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LANDMINE ARMS CONTROL

Stephen D. Biddle, *Project Leader*
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May 1996

Prepared for
Office of the Under Secretary of Defense for Policy

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PREFACE

This paper is the second of two documents prepared by the Institute for Defense Analyses (IDA) for the Office of the Assistant Secretary of Defense for Special Operations and Low Intensity Conflict under the task "Constraints on Antipersonnel Landmines in Future Conflict." The first of these documents, IDA D-1559, *The Military Utility of Landmines: Implications for Arms Control*, was published by IDA in June 1994. This second paper is broader in scope and is intended to complement, but not to supercede, the analysis in D-1559 (which provides a more detailed assessment of a subset of the issues addressed here).

The authors appreciate the contributions of many individuals. Helpful comments on earlier drafts were provided by Prof. Tami Davis Biddle of Duke University; Mr. Charles Digney of the U.S. Army Office of the Program Manager for Mines, Countermines, and Demolitions; Mr. Carl von Essen of Swedish Save the Children; Mr. Stephen Goose of Human Rights Watch; and Mr. W. Hays Parks, Special Assistant to the Judge Advocate General for Law of War Matters. The views expressed in the paper do not, however, necessarily reflect those of its outside reviewers, and responsibility for any errors or omissions remains the authors' alone. Internal IDA review was provided by Dr. Victor A. Utgoff and Mr. Robert Zirkle. Mr. Andrew Schneider provided research assistance, Ms. Shelley Smith edited the document, Mr. Mark Fritzel and Ms. Leta Horine provided typing support, and Mrs. Barbara Varvaglione provided timely and efficient production assistance. In addition, Dr. Jeffrey Grotte, Mr. Christopher Jehn, Mr. Michael Leonard, Mr. Philip Major, and LTC Douglas Schultz (U.S. Army, ret.) of the IDA staff, and MGEN Ennis Whitehead (U.S. Army, ret.), an IDA consultant, provided helpful comments at various stages in the research.

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I. INTRODUCTION AND SUMMARY

Indiscriminate landmine use has become a major humanitarian problem. Perhaps 80 to 110 million unexploded mines are now scattered over 64 countries worldwide.[1] These mines kill or maim as many as 2,000 people a month—most of them civilians, many of them children.[2] Estimates of the cumulative toll from decades of mine use run into the hundreds of thousands of deaths and injuries.[3]

Most of these injuries result from the use of small antipersonnel (AP) mines by irregular or poorly disciplined armies in the developing world. In Cambodia, for example, the 12-year civil war between the Khmer Rouge and government forces saw widespread mine use to deny opponents key transportation routes and military positions, to terrorize civilians, and to deny the population access to essential economic resources (especially arable land). As a result, an estimated 7 to 9 million mines are now distributed over a country about the size and population of the state of Georgia. Of this population, some 30,000 Cambodians—or about one out of every 230 people in the country—are now amputees as a result of landmine detonations.[4] A substantial fraction of Cambodia's national land area has been rendered uninhabitable, and the country as a whole now averages more than 100 unexploded mines per square mile.[5]

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1 United States Department of State, Bureau of Political-Military Affairs, *Hidden Killers: The Global Landmine Crisis*, 1994 Report to the U.S. Congress on the Problem with Uncleared Landmines and the United States Strategy for Demining and Landmine Control, December 1994, pp. v, 1–2. UN estimates run as high as 200 million unexploded mines worldwide: see Patrick Blagden, "Summary of United Nations Demining," in International Committee for the Red Cross, *Report of the Symposium on Anti-personnel Mines: Montreux, 1993* (Geneva: International Committee for the Red Cross, 1993), p. 117.

2 *Hidden Killers*, p. 2. See also: The Arms Project of Human Rights Watch and Physicians for Human Rights, *Landmines: A Deadly Legacy* (New York: Human Rights Watch, 1993), pp. 298–300; Statement of Elizabeth Dole, President of the American Red Cross, on the use of antipersonnel mines, press release dated 21 April 1993, p. 1

3 International Committee for the Red Cross, *Landmines: Time for Action*, 1 March 1995, Uniform Resource Locator, http://www.icrc.ch/icrcnews/323.htm, pp. 2, 4.

4 U.S. Dept. of State, *Hidden Killers*, p. 18; Human Rights Watch, *Deadly Legacy*, p. 166.

5 Given 7 to 9 million unexploded mines in a country of about 70,000 square miles. Nongovernmental estimates of the total area affected run as high as 35 percent of the national land area of Cambodia and Afghanistan: see OneWorld Online, *Landmines Special Report*, Uniform Resource Locator, http://carryon.oneworld.org/landmines/landmine_background.html#landmines, p. 4.

The problem extends far beyond Cambodia. In Angola, extended civil warfare has left an estimated 9 to 20 million unexploded mines and over 15,000 amputees (or more than one in every 470 Angolans). In Afghanistan, the war between the Soviet-supported government and the Mujaheddin rebels left behind at least 10 million mines; in Mozambique, a 15-year civil war left more than 1 million landmines and at least 8,000 amputees; in Sudan, internal warfare left 1 million mines; in Ethiopia and Eritrea, some 1.5 million. The ongoing conflict in Bosnia has so far produced an estimated 3 million unexploded mines, with millions more in the combined territories of Bosnia, Croatia, and Slovenia. In many of the world's poorest countries, large stretches of economically vital land have been rendered uninhabitable, hospitals have been burdened with the care of the wounded, and political instabilities have been aggravated by the forced movement of rural villagers from mined agricultural land into already overcrowded cities.[6]

The problem is not likely to go away any time soon. Ongoing conflicts are sowing an estimated 2 to 3 million additional mines every year.[7] And once sown, they are very hard to clear. Demining is slow, expensive, and hazardous. Most humanitarian demining is done by hand, with one trained person typically able to clear only some 20 to 50 square meters per day.[8] Clearing only the more dangerous sections of Cambodia has been estimated to require decades, and it is likely that significant stretches of mined countryside will never be cleared. More than 50 years later, for example, many World War II battlefields in Egypt and Libya remain off-limits to civilian traffic because of uncleared landmines.[9]

The gravity of this problem has given rise to three main classes of proposals for reducing the toll. One approach has been to seek more controlled, less indiscriminate mining by improving the law of war on landmine use.[10] A second is to speed the removal

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6 *Hidden Killers*, pp. 15–18; *Deadly Legacy*, pp. 145, 149, 204–5; Raymond Bonner, "Pentagon Weighs Opposition to a Ban on Mines," *New York Times*, 17 March 1996, p. 1.

7 Patrick Blagden, "The Use of Mines and the Impact of Technology," in Kevin M. Cahill, ed., *Clearing the Fields: Solutions to the Global Land Mines Crisis* (New York: Council on Foreign Relations and Basic Books, 1995), pp. 112–123 at 114.

8 *Deadly Legacy*, p. 235. Note that humanitarian demining—an area clearance operation with very high percentage clearance requirements—is a very different undertaking from military breaching, which is typically performed in narrow breaching lanes for relatively short distances with much less demanding percentage clearance requirements.

9 Ibid.

10 Especially, by amending Protocol II of the U.N. Convention on the Use of Certain Conventional Weapons (UNCCW), for example to extend its provisions to cover internal wars or to add verification and enforcement provisions. See, e.g., W. Hays Parks, "The Humanitarian Law Outlook," in Cahill, pp. 45–59. Alternatively, the UN Secretary General and some nongovernmental organizations have argued that landmines are inherently indiscriminate and are thus already illegal under existing law; in this view, what is required is reinterpretation and enforcement of current law rather than explicit

of already-laid mines by improving funding or technology for demining.[11] The third approach is to cut the number of new mines being laid by negotiating arms control agreements banning the production, stockpiling, export and/or use of mines.[12]

The purpose of this paper is to evaluate the pros and cons of the third approach—structural arms control. Where possible, we contrast the relative merits of arms control and alternative methods, but our primary focus is to develop a careful accounting of the costs and benefits of arms control per se.

Our analysis is not intended to provide a direct recommendation for U.S. government policy. This is because benefits and costs in landmine arms control are qualitatively different: reduced deaths and injuries to civilians in the developing world on one hand, and reduced U.S. military capability on the other. To balance them requires a value judgment to weigh moral responsibility to civilians in the developing world against moral responsibility to the U.S. servicemen and women whose lives are at greater risk any time U.S. military capabilities are reduced. We attempt no such value judgment here. Instead, our aim is to help measure the respective benefits and costs—and thus to inform the value judgments that must ultimately be made—rather than to undertake the judgment itself.[13]

Our principal findings are twofold. First, there are important limitations on arms control's ability to reduce civilian suffering due to landmines. The monitoring and enforcement provisions of a treaty are unlikely to impose high costs on landmine users. A

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amendment: see, e.g., Boutros Boutros-Ghali, "The Land Mine Crisis: A Humanitarian Disaster," *Foreign Affairs*, September/October 1994, pp. 9–13 at 13; *Deadly Legacy*, p. 12; "Landmines Special Report," Press Release, Vienna Working Group of the International Campaign to Ban Landmines, 6 October 1995, Uniform Resource Locator:
http://carryon.oneworld.org/landmines/vienna_updates3.html, p. 1.
Few governments share this view, however, and the wording of the UNCCW strongly implies that landmines can be used in ways that meet customary international legal requirements. For a broader review of landmine legal issues, see Parks, "Humanitarian Law Outlook."

11 See, e.g., Thomas R. Evans, "Technology Beyond the Probe," in Cahill, pp. 124–137; Blagden, "Summary of UN Demining," pp. 112–123; *Deadly Legacy*, pp. 256–60.

12 Or to redirect minelaying toward mine types considered less dangerous to civilians (such as self-deactivating or self-destructing mines), or away from mine types considered especially difficult to remove (such as metal-free, all-plastic mines). Note that none of the three basic approaches are mutually exclusive—indeed, they are arguably mutually reinforcing (see the discussion under "Conclusions" below). Note also that approaches labeled "arms control" here can also be pursued via, e.g., law of war restrictions (such as bans on metal-free or other mines, which have been proposed as amendments to the UNCCW). For illustrative arms control proposals, see, e.g., Cyrus Vance and Herbert S. Okun, "Eliminating the Threat of Landmines: A New U.S. Policy," in Cahill, pp. 198–210; Janne Nolan, "Landmines: The Arms Control Dimension," in ibid., pp. 87–96.

13 This is not to argue that such judgments cannot be made, or that the moral issues at stake are not susceptible to analysis—only that such a normative analysis is beyond the scope of this paper.

major cost increase is likely to be required, however, to persuade many developing world armies to forgo mine use on military or economic grounds. While some will respect even an unenforceable treaty rather than use weapons stigmatized by an international ban, no evidence has yet been produced to show that this will be a widespread response. To conclude that arms control will make a major difference in third world mine use thus requires an assumption, without positive evidence, that stigmatization will deter mine use even without effective enforcement.

Second, the effects of a landmine treaty on U.S. casualties in future conflicts will vary widely, depending on:

- The actual restrictions imposed by the treaty (e.g., which types of mines are limited)
- The balance of tactical offense and defense by U.S. forces
- The degree of treaty compliance by future U.S. opponents
- The mix of future conflict types (e.g., the relative frequency of major regional contingencies, lesser regional contingencies, and peacekeeping or other operations other than war)
- The nature of the terrain and the enemy forces encountered

While a landmine treaty would clearly increase prospective U.S. losses for some combinations of these factors, the magnitude of the increase is highly variable, and for some combinations a treaty might actually reduce U.S. losses. Since the conditions of future conflicts cannot be predicted with certainty, the consequences of a treaty for future U.S. casualties thus cannot be projected with certainty either.

We present these findings in four steps: (1) describing the analytic methods used, (2) assessing the potential humanitarian benefits of arms control, (3) assessing the potential military costs, and (4) drawing conclusions and implications of the analysis for arms control policy.

II. ANALYTICAL APPROACH

A. ASSESSING BENEFITS/ADVANTAGES OF LANDMINE ARMS CONTROL

Landmine arms control is intended to provide two chief benefits: (1) fewer deaths and injuries from landmine detonations, and (2) economic use of land that would otherwise be unusable because of unexploded mines. To assess either benefit fully, one would have to gauge the social effects of landmine injuries on village life, or estimate the net marginal effect of mine use on economic performance in the developing world. But underlying those issues is the first-order analytical question, Would a treaty in fact reduce minelaying, and if so, to what extent? We will concentrate here on this question.[14]

Any treaty will probably cause some reduction, but none is likely to eliminate mine use. Few arms control agreements can promise total effectiveness, and landmine controls may be easier to circumvent than most, given how easily such small weapons can be concealed compared with, say, tanks or aircraft. On the other hand, some states will comply voluntarily on humanitarian grounds, while others may be deterred from treaty violation by even a moderate risk of detection.

The question is thus one of degree: any treaty will have some effect, but how much? And which treaty types are likely to have larger effects than others?

The answer depends on the *way* one assumes the reduction would come about. There are two broad possibilities. Many landmine opponents argue that a negotiated ban will change the way mines are perceived, stigmatizing them as illegitimate and creating a norm against their use. Potential minelayers would thus reject such weapons, either because they themselves had come to view them as objectionable, or because they were

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14 Assessments of the broader economic or social impact of mine use have been undertaken elsewhere: see, e.g., Shawn Roberts and Jody Williams, *After the Guns Fall Silent: The Enduring Legacy of Landmines* (Washington, D.C.: Vietnam Veterans of America Foundation, 1995); Human Rights Watch Arms Project, *Landmines in Mozambique* (New York: Human Rights Watch, 1994), pp. 42–80; *Deadly Legacy*, pp. 117–233; ICRC, *Landmines: Time for Action*, Chapters III and IV; Boutros-Ghali, *The Land Mine Crisis*, pp. 9–13. These assessments typically focus on the relationship between the scale of mining and its economic, social, or medical consequences; they do not provide extensive analysis of the relationship between putative treaty terms and the scale of subsequent mining. The latter is our focus here.

unwilling to incur the disapproval of an international community newly mobilized to condemn such forms of war.[15]

Alternatively, with or without a change in norms, a treaty's monitoring and enforcement provisions could discourage mine use by increasing its cost and difficulty. A treaty would force potential mine users to conceal the activity, to evade the treaty's terms, and/or to accept enforcement penalties if caught in violation. While this would not make minelaying impossible, it would make it more expensive (and possibly less effective militarily). For most products, higher cost implies lower consumption; a landmine treaty could thus be expected to reduce mine use by increasing its cost, and thus changing the users' incentives for minelaying as opposed to other means of warfare.[16]

Of these two mechanisms, the strength of the second can be estimated by analyzing the putative treaties' terms, and the nature of the potential users' alternatives. But the first mechanism, stigmatization, rests on a series of as yet unproven contentions whose validity is beyond the scope of landmine control per se: i.e., that arms control can create new international norms; that norms of this type can affect the behavior of potential weapon users in general; and that the specific parties responsible for much of the landmine problem (e.g., subnational groups, third world governments, and major landmine exporters) are susceptible to such pressures. This study team was unable to identify any existing (or ongoing) research addressing the validity of these contentions for landmines. In fact, the underlying mechanism itself has received very little analytical attention as a general proposition. And the limited research that *has* been done, while inconclusive, tends to cast doubt on the effectiveness of weapon stigmatization where militaries otherwise see the use of such weapons to be in their interest.[17]

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15 See, e.g., the positions of Oxfam and CAFOD as described in "CAFOD Landmines Campaign Briefing Paper on the UN Inhumane Weapons Convention and Review Conference," Uniform Resource Locator, http://carryon.oneworld.org/landmines/weapons.htm# REVIE, downloaded 31 October 1995, p. 5; Oxfam, "Dumb and Dumber: The Landmines and the Politicians," Uniform Resource Locator, http://carryon.oneworld.org /landmines/news_landmines_dumb.html, downloaded 31 October 1995, p. 5; also *Deadly Legacy*, p. 12.

16 Note that the first mechanism, stigmatization, is arguably a special case of the second, in that it, too, involves imposing a cost (here political or psychological) on potential users, so that the scale of minelaying is reduced as potential users voluntarily respond to changing incentives. However, the determinants of the respective costs (i.e., political/psychological vice concealment, evasion, or punitive sanction) are quite different; thus, we will treat them separately here.

17 See Jeffrey Legro, *Cooperation Under Fire* (Ithaca: Cornell University Press, 1995), esp. pp. 217–235. Legro examines the pattern of use and non-use of three stigmatized weapon types during World War II (the submarine commerce raider, strategic bombing of civilian population centers, and chemical weapons). Norms against the use of all three were widely held prior to the war, yet only in the case of chemical weapons were these norms effective. Legro explains the failure of stigmatization to prevent submarine commerce raiding and strategic bombing of civilians by arguing that military organizational

While the available research is insufficient to refute stigmatization, neither does it provide much support for its effectiveness. For the time being, arms control's ability to reduce minelaying by stigmatizing mine use is thus an unknown, and one whose scope is substantially broader than the immediate issue at hand.

Accordingly, we focus here on the second of the two mechanisms described: the ability of a treaty to discourage mine use by imposing additional costs on mine users. This analytic approach is not meant to rule out the possibility that even an unenforceable treaty might still succeed by stigmatization. Rather, it is intended to make two contributions to the debate. First, it can provide a concrete assessment of one major class of arms control effect. Whether stigmatization works or not, mine users would face increased costs in the event of a treaty; by estimating the consequences of this, the analysis can contribute to a better understanding of a treaty's effects. And second, this approach can help clarify *whether one needs to rely* on an unproven mechanism to find that arms control is in the United States' national interest. That is, if cost imposition can be effective, then stigmatization's validity is moot; but if not, arguing that arms control's benefits are large requires one to assume that stigmatization can work—and it may or may not for landmines.

Such an assessment implies three analytical tasks. First, for each major treaty type, we must assess the costs of circumvention and the costs of enforcement penalties if a user is caught in violation. Second, we must estimate the relationship between increased cost and decreased consumption for mines—i.e., the *cost elasticity* of landmine use. And third, we must deduce from the combination of price increase and cost elasticity the rough net effect of each treaty type on landmine use.

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culture trumps norms. That is, where military organizations themselves dislike a weapon (e.g., poison gas), norms against its use will tend to be effective. But where some military organizations view a weapon as important to their mission and necessary for success, he argues, norms will often take second place to arguments for military necessity and stigmatized weapons will be used anyway. Note that in the postwar era, even chemical weapons have been used by some militaries in spite of the continuing stigma associated with them: see, e.g., Victor Utgoff, *The Challenge of Chemical Weapons* (London and New York: Macmillan, 1990), pp. 69–87. For other research to date on weapon stigmatization, mostly consisting of historical accounts of the development of particular norms, see: Richard Price, "A Genealogy of the Chemical Weapons Taboo," *International Organization*, Winter 1995, Vol. 49, No. 1, pp. 73ff; Nina Tannenwald, *Dogs that Don't Bark: The United States, the Role of Norms and the Non-Use of Nuclear Weapons in the Post-World War II Period* (PhD dissertation, Cornell University, 1995); also Martin Van Creveld, *Technology and War* (New York: The Free Press, 1989), pp. 71–73, which emphasizes the inconsistency in the norms attaching to particular weapon types over time. For an argument that norms or conventions can be difficult to establish, especially when physical distinctions between permitted and non-permitted weapons are subtle (note that few proponents of mine bans extend the proposed ban to cover all landmines—most address only antipersonnel weapons while permitting antitank mines), see Elizabeth Kier and Jonathan Mercer, "Setting Precedents in Anarchy: Military Intervention and Weapons of Mass Destruction," *International Security*, Spring 1996 (Vol. 20, No. 4), pp. 77–106. For an argument that any international landmine treaty must be objectively verifiable and enforceable, see Nolan, pp. 87, 88.

B. ASSESSING DISADVANTAGES OF LANDMINE ARMS CONTROL

The potential disadvantages of landmine arms control include the economic costs of monitoring and verification; the expense of converting, replacing, or destroying existing mine stocks or production facilities; and the loss of foreign trade income for states that export mines. For the United States, however, the chief potential disadvantage of landmine arms control is its effect on U.S. military performance.[18]

To estimate this effect, we rely primarily on a series of analyses using the Janus combat simulation model. Janus is a two-sided, stochastic, interactive, highly disaggregate division/brigade level computer model in wide use by the U.S. Army, Marine Corps, and National Guard, as well as the militaries of several NATO allies.[19] It has been subject to considerable empirical validation effort, especially via systematic comparison of its output with the results of U.S. Army field exercises at the Army's National Training Center at Fort Irwin, California.[20] It has attained unusually broad acceptance within the military and defense analytical communities—especially within the Army, which accepts Janus as sufficiently realistic to serve both as a major training system for preparing active duty and National Guard officers for war, and as an analytic tool for studying topics including the cost-effectiveness of alternative U.S. landmine systems.[21]

18 For detailed estimates of arms control monitoring and implementation costs, see Dan Levine, *The Costs and Effectiveness of Treaty Verification Regimes*, IDA Paper P-2650 (Institute for Defense Analyses, Alexandria, VA, 1992); Julia Klare and Jeffrey Grotte, "Reducing Cost While Maintaining Effectiveness in Arms Control Monitoring," in James Brown, ed., *Challenges in Arms Control for the 1990s* (Amsterdam: VU University Press, 1992). By way of illustration, current monitoring and implementation costs range from $760 million over 15 years for the START treaty to $490 million over 13 years for the INF treaty or $77 million over 15 years for the CFE treaty. The Chemical Weapons Convention, or CWC, has projected costs of roughly $270 million over 15 years without commercial facility inspections and $2.5 billion with them. Assuming that costs for a landmine treaty were similar, and that the U.S. were only one of many signatories, costs to the U.S. could thus be expected to be some fraction of such a total.

19 More specifically, the analyses were conducted using Janus-Army version 3.17, Open Systems. For a more detailed description of Janus, see Department of the Army, *User's Manual, Janus 3.X/UNIX*, Headquarters, TRADOC Analysis Center, ATRC-ZD, Ft. Leavenworth, KS 66027.

20 See, e.g., L. Ingber, H. Fujio, and M. F. Wehner, "Mathematical Comparison of Combat Computer Models to Exercise Data," *Mathematical Computer Modeling*, Vol. 15, No. 1, 1991, pp. 65–90; L. Ingber, "Mathematical Comparison of Janus(T)," in S. E. Johnson and A. H. Lewis, eds., *The Science of Command and Control: Part II—Coping with Complexity* (Washington, D.C.: AFCEA International Press, 1989), pp. 165–176.

21 On the use of Janus for Army officer training, see, e.g., National Simulation Center, *Training and Simulation: A Handbook for Trainers* (Ft. Leavenworth, KS: U.S. Army, 1994); on the Army's use of Janus for landmine effectiveness analysis, see fax communication from CMDT, USAES, Ft. Leonard Wood, 1 June 1994, on the recent Mine Benefit Analysis conducted by the U.S. Army Engineer School at Ft. Leonard Wood. Of course, other models are sometimes used for this purpose as well, such as CASTFOREM; see, e.g., H. A. Freeberg and W. L. Fuller, *Countermobility in Support of AirLand Battle Study: Combat Power of Minefields* (Ft. Leavenworth, KS: TRADOC Analysis Command,

The purpose of these simulation analyses is to produce a series of controlled experiments in which landmines are added to or subtracted from the battle on one or both sides, and the effects of those variations on simulated outcomes are observed. The results enable us to estimate the marginal effect of landmine availability on U.S. losses for the particular scenario conditions assumed.

Of course, combat results (including the effects of landmines) are sensitive to scenario conditions such as terrain, tactics, or objectives. With the uncertainty of the post-Cold War era, no one can know just what these conditions will be for any given future combat action.

As a result, we have structured the simulation experiments as sensitivity analyses in which we systematically vary key scenario conditions and observe how these variations affect combat outcomes (particularly, the effectiveness of mines). In this way we can determine what conditions we must assume in order to obtain landmine effectiveness results like those found in the public debate, and thus, how robust the typical effectiveness estimates are in the face of uncertainty over the nature of future conflict.

September 1992). No topic is the exclusive province of a specific model, but Janus is accepted as an appropriate model for the topic of landmine effectiveness.

III. BENEFITS OF LANDMINE CONTROLS

While the public debate offers few explicit assessments of arms control benefits, landmine opponents often imply that the benefits will be quite large.[22] Our analysis, however, suggests that benefits may be more limited for two reasons: (1) landmine costs are unlikely to increase very much because of arms control, and (2) any cost increase will most likely have to be significant to effect a large reduction in landmine use.[23]

A. INCREASING THE COST OF LANDMINE USE

Arms control can impose two kinds of costs on landmine users: evasion (or concealment) costs associated with disguising the activity, and punitive sanctions imposed on violators if discovered. The two are not necessarily additive. If a violation is concealed successfully, sanctions are not triggered and their potential costs matter little. But if sanctions are weak or lacking in credibility, concealment matters less and violators will not undertake expensive concealment efforts. To estimate arms control's total effect on the

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22 U.N. Secretary General Boutros Boutros-Ghali, for example, suggests that a total ban can make "sustained headway against . . . . these terrible weapons:" Boutros-Ghali, "The Land Mine Crisis," p. 13. U.S. Senator Patrick Leahy believes there is a "realistic chance" that a landmine ban "can stop the killing of civilians by antipersonnel landmines:" Statement of Sen. Patrick Leahy as quoted in Cyrus Vance and Herbert Okun, "Eliminating the Threat of Landmines," in Cahill, pp. 198–210 at 205; Cornelio Sommaruga, President of the International Committee of the Red Cross, described a total ban as a "truly effective solution:" Statement of Sommaruga, Feb. 24, 1994, as quoted in ibid., p. 205; Cyrus Vance and Herbert Okun conclude that a ban could "drastically reduce" landmine use: Vance and Okun, p. 208. The British NGO CAFOD argues that unilateral Western export moratoria can lead to a "truly international ban," which they suggest can cause such weapons to cease to exist: "CAFOD Landmines Campaign Briefing Paper," p. 5. Oxfam, while conceding that a ban is not "a fail-safe solution," nevertheless argues that a landmine ban would be broken only by a minority, and limited only to "small-scale illegal production;" a total ban could "reduce proliferation significantly:" "Dumb and Dumber: The Landmines and the Politicians," p. 5. Not all arms control proponents are as sanguine. Human Rights Watch, for example, suggests that "a ban on production and export will surely not drive all producers from the field," but will still reduce mine use sufficiently to warrant adoption: *Deadly Legacy*, p. 13. Janne Nolan concludes that "clandestine commerce in land mines is likely to continue" even under an export ban, though, again, not to such a degree as to make a ban inadvisable: Janne Nolan, "Land Mines: The Arms Control Dimension," in Cahill, pp. 87–96 at p. 93. Nevertheless, the literature as a whole implies very substantial (if unquantified) potential effectiveness in reducing mine use.

23 To conclude that such benefits will be large, one must assume (without positive basis in the literature) that stigmatization can be effective for landmines; see Section B.1.

costs of landmine use, we must therefore assess the potential severity and credibility of punitive sanctions, the cost and effectiveness of potential evasion options, and their interaction.

Of the two types of costs, evasion costs vary by treaty type because different treaties require different monitoring methods which have different strengths and weaknesses. We therefore discuss evasion costs (and evasion effectiveness) for each major treaty type, and then assess the sanctions that could be applied to violators of any treaty type. We then estimate the total cost of the two taken together.

1. Evasion Costs

a. Evading Production Bans

Arms production bans are ordinarily monitored through observation of facilities declared by treaty signatories as potential production sites. This monitoring can be accomplished in several ways. Periodic on-site inspections (OSI) of the declared facilities can be conducted, either on a routine, scheduled basis or as "challenge" inspections on limited notice. Continuous surveillance can be provided by basing inspectors permanently at the site or by installing unmanned remote sensors such as TV cameras, infrared scanners, scales, or motion detectors. Production can be deduced after the fact by auditing facilities' input and output records. Alternatively, national technical means (NTM) such as satellite imagery, communications intercepts, or human agents can be used.[24]

What would a violator need to do to evade such monitoring? One approach would be to shift production to states outside the ban. It is unlikely that all states would participate in a production treaty. Even if only a few declined to join, potential violators would have an economic incentive to shift production into those states (with an associated cost increase equal to the startup cost of establishing new plants in suitably permissive countries; see Section C.1.b, below).

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24 For a review of methods for monitoring arms production bans, see Ivan Oelrich, "Monitoring Production of Conventional Weapons," in *Verification of Conventional Arms Control in Europe: Technological Constraints and Opportunities* edited by Richard Kokoski and Sergey Koulik (Boulder, Colorado: Westview Press, 1990), pp. 155–163. Note that an extensive program of OSI can involve significant costs and could require the establishment of a new international agency for implementation: see, e.g., Jeffrey Grotte and Julia Klare, *Balancing Cost and Effectiveness in Arms Control Monitoring*, IDA Paper P-2756, Institute for Defense Analyses, Alexandria, VA, 1992, pp. III-27 to III-30, III-34. Note also that NTM, while theoretically applicable to landmine production ban monitoring, are scarce, high-value national assets that will not ordinarily be devoted to such purposes on a regular basis.

Alternatively, producers in treaty member states might seek to conceal the activity. While violators might be able to do this by disguising illicit production at a declared site, the aforementioned monitoring methods can make this difficult.[25] Production at *un*declared sites is much harder to discover, and will often be the more attractive strategy for potential violators. Undeclared sites typically cannot be inspected without prior evidence of wrongdoing, yet landmines can be produced without providing much externally observable evidence. Landmine production monitoring is thus something of a catch-22: to obtain evidence requires access to the facility, but access to the key (undeclared) facilities normally requires prior evidence.[26]

Undeclared landmine production is hard to detect because the component parts are so similar to common commercial products, and because they can be assembled in ordinary commercial structures with few special distinguishing features. In general, landmines consist of a casing, an explosive filling, and a fuse or detonator. Most mass-manufactured casings are made of extruded plastic or simple cast- or sheet-metal. The resulting shapes and materials are similar to thousands of ordinary commercial products, from toys to soda bottles or aluminum cans. In fact, it is not uncommon for current mine casing production lines to be used for other goods when not needed for mines. Valsella, for example, an Italian subsidiary of Fiat and a major landmine producer, operates a plastic parts plant that alternates between automobile dashboard parts and landmine casings, depending on demand.[27]

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25 For a general review and assessment of such methods, see Ivan Oelrich, *Conventional Arms Control: The Limits and Their Verification* (Lanham, MD: University Press of America, 1990), Harvard University Center for Science and International Affairs Occasional Paper No. 8.

26 Historically, states have been reluctant to allow unlimited access to arms control monitoring teams, since this would open legitimate defense activities to espionage under the guise of treaty verification, and, according to some, present an unacceptable infringement on rights of national sovereignty. See, e.g., Utgoff, pp. 88–128; H. Martin Lancaster, "Chemical Proliferation and Disarmament: A Congressional Perspective," *Chemical Weapons Convention Bulletin*, March 1991, pp. 1–5; Stephen J. Ledogar, "Banning Chemical Weapons: The Geneva Perspective," Remarks Before the Senate Foreign Relations Committee, 22 May 1991, p. 4. Some delineation of permissible and impermissible areas for inspection is thus likely to be a necessary component of any arms production ban not wholly dependent on national technical means (some of which, e.g., satellite surveillance, do not necessarily require site declaration); however, this delineation could conceivably be accomplished by declaring some areas off-limits and permitting inspections elsewhere, rather than by declaring sites at which inspection is allowed and forbidding it elsewhere, as described above. Alternatively, delineation could be accomplished through a requirement to show probable cause to obtain access, or by limiting access to parts of an inspected site. Note, however, that the evasion issues treated below are similar regardless.

27 Telephone interview, Thomas Reeder, U.S. National Ground Intelligence Center, Charlottesville, VA, 29 November 1995.

Explosive fillings for landmines can be any of a wide variety of common compounds. The blast effect needed for an AP landmine is very small; hence, no special or unusually efficient explosive is needed. Current mass-manufactured mines use fillings ranging from TNT to RDX, but almost any readily available commercial explosive would do about as well.[28] Such materials are widely traded, and landmine applications would constitute only a small fraction of the ongoing, legitimate trade.[29]

Fuses or detonators can likewise be very simple, using materials that are widely used commercially. The same primary explosives used in blasting caps or small arms ammunition will detonate ordinary landmine charges, while even fairly elaborate AP fuses consist of nothing more than simple electrical circuitry or mechanical devices based on springs or frangible capsules.[30]

Similarly, there are no distinctive properties to the buildings or plant associated with assembling these components. The Italian mine manufacturer Valsella, for example, performs final assembly in an 11,500 square meter rectangular structure that includes production lines for other products. Even this facility, which was not adopted with concealment in mind, is externally indistinguishable from thousands of other industrial buildings—it is roughly the size and shape, for example, of the Coca Cola bottling plant in Alexandria, Virginia.[31]

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28 See, e.g., Christopher F. Foss and Terry J. Gander, eds., *Jane's Military Vehicles and Logistics, 1993–94* (Coulsden, Surrey: Jane's Information Group, Ltd., 1993), henceforth *Jane's*, pp. 177–250.

29 The U.S. alone produced about 69,000 tons of commercial explosives in 1990, or about 100 times the amount needed for the entire world's annual AP landmine production: see *Encyclopedia of Chemical Technology*, Fourth Edition, Vol. 10 (New York: John Wiley & Sons, 1993), p. 49; for annual landmine production see *Deadly Legacy*, p. 36; for explosives content see *Jane's*, pp. 185, 187, 213 (assuming an average of the Chinese Type 72, the Russian PMN, and the Italian VS-50 for a representative per-mine weight of explosives). In the mid-1980s, the Nobel Kemi division of Nobel Industries transferred to Iran in a single illegal shipment some 400 tons of military explosives, or a quanity sufficient for perhaps half the year's entire global AP mine production: Michael T. Klare, "The Thriving Black Market for Weapons," *Bulletin of the Atomic Scientists*, April 1988, pp. 16–24 at 17. In countries, like the United States, with extensive regulatory controls on explosives trading, it might be difficult to conceal even this level of market activity in a closely regulated product. In much of the world, however, regulation is much weaker, and even where regulation is relatively tight, covert manufacture of the explosives themselves from legitimate raw materials could be undertaken at modest expense. Today it is not uncommon for mine casings and fuses to be manufactured in one country and exported unassembled for filling and final assembly elsewhere; it would not be difficult for violators to reserve the handling of explosive fillings for countries where regulations are permissive. Alternatively, if some governments (or even individual officials) collaborate with manufacturers to circumvent a mine production ban, then even strong national regulations on explosives trading could be ineffective.

30 See, e.g., *Jane's*, pp. 177–250.

31 Coca Cola's brick structure of roughly 12,000 square meters (about 150 by 80 meters) is located roughly a half mile from the Institute for Defense Analyses. The Valsella facility description is taken from a company brochure, "Valsella Meccanotecnica."

A violator's best strategy for operating within a treaty state would thus be to set up a new, undeclared facility designed to resemble a legitimate business. How effective would this be? No concealment strategy can guarantee permanent secrecy. The most any violator can expect is to delay discovery, to limit it to a part of the activity, or to create ambiguity so as to complicate enforcement decision making—whether the activity is illegal landmine production or illegal drug smuggling. By this standard, production concealment for landmines is likely to be highly effective. Systematic global monitoring of undeclared production is probably impractical, given the lack of external cues. Most discoveries will thus be serendipitous, or the result of long-term observation of patterns in landmine use. The odds of such detection cumulate over time, but immediate discovery is unlikely. And any given discovery is unlikely to reveal an entire illegal operation at once. Potential violators are thus likely to be able to conceal their activities for considerable periods, and to limit individual discoveries to components.

How much would such an approach cost? Camouflage per se would impose little additional expense, since current landmine manufacturing is already so similar to other business activity. Most of the cost would be the startup expenses of bringing a new plant into production. Without computing a specific price for a given plant, some insight into the general magnitude of such costs can be gained from the structure of the existing landmine industry. Other things being equal, industries with large startup costs typically have a few, large producers—small firms which cannot spread large startup expenses over a large sales volume are forced out by competitors with greater economies of scale. The landmine industry, by contrast, is characterized by many producers that are often quite small, or that devote a modest effort to landmine manufacture. About 100 firms worldwide produce landmines.[32] By contrast, global fighter aircraft production is concentrated in fewer than a dozen firms, tank production in about ten, and high performance jet engines in only eight.[33] This suggests that startup costs in landmine manufacture, while surely nontrivial, are likely to be relatively small.

How small is "relatively small?" While we cannot compute a precise figure, we can at least establish an upper bound. Hand production in a rural village environment using unspecialized materials and unskilled labor is the practical upper limit on the inefficiency that can be imposed on landmine manufacture by arms control. Such methods are feasible

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32 Human Rights Watch, *Deadly Legacy*, p. 36.

33 See, e.g., Paul Jackson, ed., *Jane's All the World's Aircraft, 1995–96* (Coulsden, Surrey: Jane's Information Group, 1995); Christopher Foss, ed., *Jane's Armour and Artillery, 1994–95* (Coulsden, Surrey: Jane's Information Group, 1994).

anywhere in the world, are effectively undetectable (while individual workshops might be discovered by chance, systematic monitoring would be impossible), and are available as a last resort to any party who wishes to manufacture mines. While these methods have rarely been undertaken given the historically easy availability of mass-manufactured mines, there are exceptions. In El Salvador, for example, anti-government guerrillas produced at least several thousand mines in the mid-1980s using such methods in small village workshops.[34]

Following the Salvadoran design, the IDA study team fabricated a handmade mine using about $2.10 of hardware store materials and under 20 minutes of labor.[35] Given typical third world labor costs, materials and labor would cost less than $3.[36] Other costs are harder to establish. Materials, though simple, must be procured in appropriate quantity and delivered to production sites. Product quality and consistency would be lower than for mass-manufactured mines (though more than adequate to provide a serviceable weapon).[37] Perhaps most important, assembly by hand in unspecialized facilities is more dangerous to workers than industrial production. To retain a work force long enough to produce mines in quantity would thus probably require some form of compensation for death or injury. The U.N., for example, provides life insurance for locally trained deminers in the developing world; if we assume an accident rate for mine assembly similar to that of demining (i.e., one accident per 1,000 to 2,000 mines), and accident compensation of about ten times annual income in the event of death or injury, then accident compensation payments might add an additional $7 or so to the net cost of producing a mine in this manner. If so, the net total of materials, labor, and accident compensation would still be

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34 Blagden interview; telephone interview, M. Jean-Pierre, International Disaster Assistance, Brussels, Belgium, 22 May 1995; see also Human Rights Watch, *Deadly Legacy*, pp. 184–87; Human Rights Watch, *Land Mines in El Salvador and Nicaragua* (New York and Washington: Human Rights Watch, 1986), pp. 23–27. Of course, the use of field-expedient or other locally fabricated mines has not been limited to El Salvador; the Viet Cong and North Vietnamese made extensive use of such devices in the Vietnam War: see, e.g., refs. in note 49, below.

35 Note that while the fabricated mine contained no explosives, the cost estimate assumes a TNT filling and commercial blasting caps. A detailed description is provided in Ivan C. Oelrich, *Memorandum for the Record: Landmine Construction Requirements*, Institute for Defense Analyses, 31 October 1995.

36 In 1990, for example, Salvadoran manufacturing workers earned an average of about $0.50 an hour: *Statistical Yearbook*, 39th Issue, 1994 (New York: United Nations, Department of Economic and Social Information and Policy Analysis, Statistical Division, 1994), pp. 319–26, 792–803.

37 Most of the Salvadoran mines, for example, had become duds after about four years in the ground, whereas a mass-manufactured mine can remain active for decades: Reeder interview. On the other hand, few military purposes require even four years of effective life for deployed landmines. While any modern, mass-manufactured mine will provide superior quality, the importance of the difference for actual military use is less clear.

less than $10—or just over three times the cost of the cheapest mass-manufactured mine now available.[38]

b. Evading Export Bans

An export ban could be monitored in three ways. States could incorporate into their export licensing procedures a requirement that customs officials inspect shipments for landmines. States could voluntarily exchange data on commerce in mines or mine-related products.[39] Or they could rely on national technical means.

What would a violator need to do to evade such monitoring? The answer depends on who the violator is. If the violator is a government, evading export licensing provisions means simply declining to enforce one's own customs regulations. Data exchanges could be circumvented by withholding or falsifying information. Either of these could be accomplished without cost, and would be plausibly deniable by the violator for all but the most egregious violations. Concealing landmine transfers from foreign national technical means is somewhat more challenging, but attentive exporters can readily make NTM detection of weapons as small as landmines very difficult.[40] Governmental violation would thus be cheap and potentially very effective.

If the violator is a private firm, export bans could be circumvented either by smuggling or by shifting manufacture to states outside the ban. As for the former, landmines' small size makes it relatively easy to hide shipments from customs inspectors. A shipment of 10,000 mines the size of the Valsella VS-50, for example, could be contained in fewer than a dozen ordinary 4- by 4- by 3-foot crates.[41] Landmine transfers many times this size could thus easily be hidden among the millions of cubic feet of goods passing through major seaports every year, making it relatively easy for smugglers to slip

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38 The cheapest current AP mine is generally held to be the Chinese Type 72, which reportedly can be obtained for $3; estimates of average worldwide AP landmine costs have been around $10 each: see, e.g., *Deadly Legacy*, pp. 56–57. For worker income figures, see reference in note 36, above.

39 Voluntary data exchanges are currently used for the U.N. Conventional Arms Registry, for example, and in export control monitoring for the NPT: on the former, see, e.g., Ian Anthony, "Assessing the UN Register of Conventional Arms," *Survival*, Winter 1993–94, pp. 113–129; on the latter, see "Treaty on the Non-Proliferation of Nuclear Weapons," London, Washington, and Moscow, 1 July 1969.

40 For example, by keeping mines concealed in plain shipping crates whenever outside buildings or other overhead obstruction; after-the-fact identification of an exporter by discovery of imported mines in the destination state could be complicated by manufacturing mines to foreign, or common international, designs.

41 Given an assumed total shipping volume per packed mine of 5 by 5 by 3 inches (the Valsella VS-50 itself is a cylinder of roughly 3.5 inches diameter and 1.8 inches height: *Jane's*, p. 213).

shipments through departure ports undetected.[42] While eventual discovery is inevitable, it is unlikely to occur quickly, and often may involve only the interception of individual shipments.

Of course, smuggling of any kind will, other things being equal, increase the price of the illegally shipped goods. Smugglers demand risk premiums for their services; bribes and inefficient transport methods impose added costs; and profit margins must be wide enough to accommodate occasional confiscations of discovered contraband. While this cost increase is difficult to predict for a crime that has not yet appeared, black market trading in small arms and narcotics provides at least some, albeit imperfect, basis for analogy. For the former, anecdotal reports suggest markups of as much as 10 to 20 times the nominal sales price for weapons and spare parts smuggled into Iran during the Iran-Iraq War.[43] For the latter, economic analyses of the drug trade suggest a cost premium of as little as 25 percent on cocaine smuggled into the United States across the Mexican border.[44] While the uncertainties are obviously great, it might not be unreasonable to suppose that arms control could impose a cost increase on privately smuggled landmines of anywhere between 25 percent to perhaps a factor of 10 or more.

Alternatively, private firms could simply shift manufacturing to states outside the ban.[45] As with the production ban discussed above, it is unlikely that all states would participate in an export limit, creating an economic incentive for exporters to shift the locus

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42 In fact, even a substantial landmine smuggling effort would constitute only a tiny fraction of the now-ongoing black market trade in conventional weapons. This trade has been estimated at between $1 billion and $10 billion a year; even if the world's entire current production of AP mines were diverted into the black market following an export ban, this would still constitute only about 2 to 5 percent of the ongoing illegal weapons trade. On the black market in conventional arms, see Michael Klare, "The Thriving Black Market," esp. p. 16; "The Covert Arms Trade," *The Economist*, 12 February 1994, pp. 21–23, esp. p. 21; Edward J. Laurence, "The New Gunrunning," *Orbis*, Spring 1989, pp. 225–237. Nor are illegal landmine exports uncommon even today; for illustrative examples, see Human Rights Watch, *Deadly Legacy*, pp. 60, 79, 97, 198.
Alternatively, since landmine components are so similar to legitimate products, if smugglers shipped disassembled mines for final assembly at the destination, it would be difficult to identify them as illegal goods even if discovered. In fact, landmines are often shipped as components today for reasons having nothing to do with evading export controls: see, e.g., *Deadly Legacy*, pp. 80, 97. It is unlikely that a more widespread move to disassembled shipment would induce a major cost increase, but it would significantly complicate export monitoring.

43 Michael Klare, p. 18; see also "The Covert Arms Trade," *The Economist*, 12 February 1994, pp. 21-23.

44 J.P. Caulkins, *Evaluating the Effectiveness of Interdiction and Source Country Control*, RAND Paper RP-410 (Santa Monica, CA: RAND, 1995).

45 In fact, there are already examples of such shifts as a means of avoiding national export limits. Valsella, for example, responded to an Italian ban on weapon exports to Iraq by forming a new company in Singapore, obtaining an Italian license to export mines to the new firm, then shipping them from Singapore to Iraq. Between 1982 and 1985 Valsella transferred at least 9 million mines by this route: *Deadly Legacy*, p. 198.

of production to treaty nonmembers. Here, too, the associated cost increase would be mostly that of establishing new plants in the appropriate countries. And here, too, an upper bound on the resulting cost increase would be that of hand manufacture in the intended country of use, an amount which we estimated above to be about three times the cost of the cheapest current mines.

In fact, this estimate is also an upper bound on the cost increase achievable by an export ban as a whole, since any smuggling that produced higher prices than a factor-of-three increase would be forced out of the market in favor of some form of indigenous production. Given the cost analysis for handmade mines provided above, an export ban might thus raise mine use costs by at most a factor of about three, and the actual figure could be considerably less if nonparticipant states provide havens for cheap industrial production.

c. Evading Stockpile Limits

Limits or outright bans on landmine holdings could be monitored through on-site inspection of declared or suspected stocks, and through national technical means.[46] As with production monitoring, monitors presumably would not be allowed access to inspect undeclared sites unless there were advance evidence of wrongdoing.

What would a violator need to do to evade such monitoring? Storing landmines at undeclared locations is likely to be the easiest, most effective approach. This is because landmine storage, like mine production, can be accomplished with few unique, externally observable signatures. It could thus be hard to know where to look for undeclared stocks, and hard to provide evidence to justify searches at undeclared locations.

Landmine storage methods are neither distinctive nor uniform. Because mines are small and no more hazardous than many other explosives, they can be stored in the same ways any other form of ammunition or explosive can be stored. And these vary widely. In the West, most ammunition stocks are held in arsenals or designated ammunition storage sites during peacetime for reasons of safety and efficiency. But even in the West, at any given moment stocks may be dispersed on trucks, carried by individual soldiers, held in

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46 On-site monitoring would probably also track excess stock destruction as the treaty entered into force to ensure that pre-existing stocks are not diverted into hidden storage or transferred improperly to other states.
Note that partial limits, or sublimits pertaining to specific mine types (e.g., subceilings on non-self-deactivating mines) would be more challenging to monitor than outright stockpiling bans. For an outright ban, discovery of any illegal mines proves violation. For partial limits, one must discover enough mines (of the right types) to show that total holdings exceed the limit, a task that will often require more extensive information: see Section C.1.d, below.

ships or on railroad cars, or deployed in dispensers on platforms ranging from armored vehicles to helicopters. In the developing world, nominal peacetime storage is often less systematic and can include any of the methods already mentioned, as well as underground caches, unspecialized small buildings, or tents; indeed some developing countries may lack altogether the systematically controlled central storage one finds in Western practice.[47] Special safety precautions are not necessarily present; even without the added motive of concealing forbidden weapons, it is already common for developing world armies to store munitions in ways considered highly dangerous in the West.[48]

Moreover, in territory whose ownership has changed (e.g., ground that has been captured from an opponent, or whose control has been disputed), the ownership of discovered stocks may not always be obvious. Many mine designs are used by many armies, while insurgents in particular often use captured mines themselves—sometimes in large numbers.[49] An underground cache found to contain landmines thus may or may not provide enough evidence to identify the mines' owner. Eyewitness accounts from local civilians or prisoners of war may sometimes provide the needed evidence, but the information will not always be conclusive or available.[50]

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47 Reeder interview, 29 November 1995.

48 Examples include storing explosives and gasoline together in the same enclosure, or piling detonators loosely on the floor: interview, LTC Douglas Schultz, USA ret., Institute for Defense Analyses, 31 October 1995.

49 In one incident alone from the Vietnam War, for example, Viet Cong guerrillas dug up and removed at least 5,000 of a 31,000-mine barrier system laid by Australian troops near the DMZ; most of the mines were then used against their former owners: Frank Frost, *Australia's War in Vietnam* (Sydney, London and Boston: Allen and Unwin, 1987). Throughout the war, mines captured from U.S. or Allied troops constituted a significant fraction of Viet Cong and North Vietnamese Army (VC/NVA) mine use. A 1969 U.S. Army analysis, for example, concluded that over 16 percent of all VC/NVA mines and almost 40 percent of the booby traps encountered by U.S. troops between 1 March and 10 June 1968 were of U.S. manufacture: *TC 5–31: Viet Cong Booby Traps, Mines and Mine Warfare Techniques* (Washington, D.C.: Headquarters, Department of the Army, 1969), pp. 5-2 to 5-3; on VC/NVA use of captured and field expedient mines and booby traps generally, see also U.S. Marine Corps, *Professional Knowledge Gained from Operational Experience in Vietnam, 1965–1966* (Washington, D.C.: Department of the Navy, Headquarters, U.S. Marine Corps, 1967), pp. 267–69.

50 Of 47 mine victims in Angola interviewed by Africa Watch in 1990, 22—or almost 50 percent—could not identify which side was responsible for the mining; in a similar survey in 1992, 12 of 45 victims could not identify the mines' owner: Human Rights Watch, *Deadly Legacy*, pp. 157–58. And not all reports are necessarily accurate: see, e.g., ibid., p. 181. Of course, even if the owner is unidentifiable, discovery of an unaccompanied stockpile might be considered grounds for destroying the discovered stocks—a form of sanction (see sanctions discussion below), albeit less severe than some that might be triggered against an identified state violator.

To establish violation, however, requires reasonably clear identification of the mines' owner. A state cannot be held liable for the actions of its enemies in war, even if those actions occurred on its soil.[51] To the extent that it cannot be determined which combatant established a stockpile, treaty enforcement would thus be moot regardless of the stockpile's location or apparent propriety under the treaty.

Thus, even today, virtually any enclosed structure or vehicle could store landmines whose ownership may not always be clear even if discovered. To locate or count a state's stockpile would thus be difficult even without a deliberate effort by the target to conceal its holdings; a party that wished to store mines surreptitiously and was willing to change its behavior moderately could make monitoring even harder still.

Of course, as with production or export controls, some part of an illegal stockpile is likely to be identified eventually. Sooner or later evidence will emerge: local civilians will discover caches or see soldiers putting mines into storage and report this to inspectors, deminers, or humanitarian organizations; defectors or prisoners of war will describe violations; or combatants will capture stocks created unambiguously by hostile treaty members and report them.

How long this will take depends on the type of limit. For a total ban, discovery of *any* clearly identifiable stockpile establishes violation. Stockpile ceilings or other partial limits, on the other hand, require much more information to prove a violation; rarely will chance discovery of one or two hidden caches suffice in itself. Total bans are thus harder to evade successfully for an extended period. Concealment is likely to be considerably more effective against treaties with partial limits.

Either way, though, evasion is unlikely to be expensive, involving mostly the dispersal or concealment of concentrated stocks, the use of less distinctive mine types, and/or the adoption of storage methods typical of one's opponent. If the treaty is a total ban on stockpiling, such evasive efforts are likely to be inexpensive but less effective; if the treaty calls only for numerical ceilings, evasion is more likely to be both cheap and successful.

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51 France, for example, is not responsible for German war crimes committed on its soil during World War II. For a more general discussion, see L. Oppenheim, *International Law: A Treatise*, 8th ed., (London: Longmans, 1955), e.g. pp. 925–28.

d. Evading Use Limits

Bans on mine use would likely be monitored by voluntary reporting after the fact. Mine victims' representatives, for example, might notify a standing commission formed under international auspices, which could then dispatch fact-finding teams as necessary to verify the reports.[52]

How could violators evade such monitoring? One strategy would be to discourage reporting by individuals or groups through intimidation, or to deny access to fact-finding teams. Intimidation tactics are common in police states. If aggressively applied, they can substantially reduce politically damaging activity in government-controlled areas.[53] But their effectiveness depends on circumstances. They work best when used by authoritarian regimes to conceal injuries to civilians within their own borders. Victims outside the regime's control, however (such as guerrillas, or civilians in territory lost to insurgents or foreign invaders), would have both the opportunity and the incentive to report their injuries.[54] Similarly, denying access to fact-finders would be most effective for concealing violations in territory controlled by the violator, and much less effective outside such areas.

Alternatively, violators could seek to obscure the timing or responsibility for minelaying. As for the former, mines planted before a ban took effect would have been sown legally. Effective monitoring would therefore require the ability to show whether injuries were caused by mines planted after the ban went into effect.

Sometimes, meeting this standard will be straightforward. Very recent mine use may be identifiable by context, such as freshly dug holes for buried mines, or an absence of undergrowth surrounding surface-laid mines. Alternatively, in areas where warfare begins only after the treaty comes into force, any observed use of controlled mines presumably supervenes the treaty and is identifiably illegal.

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52 France has proposed such a system as a means of monitoring compliance with the UNCCW Landmine Protocol: see "Draft Amended Protocol on Prohibitions or Restrictions on the Use of Mines, Booby Traps, and Other Devices (Protocol II)," Working paper submitted by France, Group of Governmental Experts Meeting, First Session, Geneva, 28 February to 4 March 1994, CCW/CONF.I/GE/3, 2 March 1994.

53 On the repressive methods employed by Saddam Hussein's Ba'athist regime in Iraq, for example, see Efraim Karsh and Inari Rautsi, *Saddam Hussein: A Political Biography* (New York: The Free Press, 1991); Judith Miller and Laurie Mylroie, *Saddam Hussein and the Crisis in the Gulf* (New York: Random House, 1990).

54 Where attempted, however, evasion by repression is unlikely to impose significant costs: few police states' internal security efforts will be driven by the need to control mine informants as such.

In other circumstances, however, the job will be harder. Minefields not immediately detected become overgrown or weathered and thus become harder to date by inspection. In areas where conflict predates the treaty, minefields not clearly of recent vintage may be hard to assess. The world's battlefields already contain some 80 to 110 million legally sown mines. Few of their locations were marked or recorded, and the mines can remain active for a long time—possibly decades. Unfortunately, demining efforts, at the current rate, will take decades to remove the problem. In all likelihood, millions of legally sown mines in unknown locations will thus predate any treaty. Distinguishing these from later, illegally sown mines may not always be a trivial task.

As for responsibility, the user's identity may not always be easy to infer from the fact of a mine explosion. As noted above in connection with stockpiling, where ground has changed hands and the mine types in use are common, it may be hard to prove which of the combatants sowed a given minefield. Villagers or other eyewitnesses to the mining may know who was responsible, but reliable eyewitness reports will not always be available. Alternatively, tactical circumstances may provide clues, but mining behavior in the developing world is diverse enough that these will not always be decisive.[55] As with timing, the miner's identity may thus be difficult to determine unambiguously even without deliberate attempts at concealment.

Potential violators who wished to aggravate these ambiguities could reduce the distinctiveness of illegal minelaying by using the same mine types as their opponents, or by using mines similar to those used prior to the ban in the same area. Parties may also seek to frame opponents by laying mines in ways likely to be discovered and blamed on the other side. In Bosnia, for example, there have been widespread reports of combatants sniping or firing mortars into friendly towns in an attempt to persuade international observers that their enemies did so (and thereby to induce international action against their opponents).[56] An aggressively enforced ban on landmine use would create a similar incentive.

The effectiveness of such techniques is likely to be mixed. Mine use is inherently harder to conceal than manufacture, export, or stockpiling since use creates victims with an incentive to report the activity. Establishing that the use was actually illegal may be

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55 On developing world mine use, see, e.g., Human Rights Watch, *Deadly Legacy*, pp. 16–35; 149–233; *Landmines in Mozambique*, pp. 28–35; *Landmines in El Salvador and Nicaragua*, pp. 23–26, 39–41; Reeder interview; Blagden interview.

56 See, e.g., Michael O'Connor, *The New York Times*, 1 August 1995, p. A-5; David Binder, *The Nation*, 2 October 1995, p. 336; Hugh McManner, *The Sunday Times* (London), 1 October 1995.

difficult, but the basic activity itself is much easier to detect than for other kinds of limits. As a result, evasion is likely to be correspondingly less effective.

But effective or not, such techniques are unlikely to be expensive. Attempts to evade use monitoring will most likely seek to exploit the inherent ambiguities of establishing age and identity; the limited means available to aggravate these ambiguities would involve little added cost.[57]

2. Sanctions Costs

The second type of cost that arms control could impose on violators is punitive sanctions. Sanctions are rarely spelled out as such in multilateral arms treaties, many of which contain no enforcement provisions at all.[58] Some treaties enjoin the parties to determine appropriate punitive actions upon notice of violation, but do not specify these actions in advance.[59] While in principle a landmine treaty could incorporate a wide variety of explicit sanctions, there is little precedent for this in other treaty experience.

The absence of explicit sanctions provisions poses three related problems: the credibility of sanction threats, the tension between enforcement and participation, and the lack of application to subnational groups. As for the first, vague enforcement provisions maximize the international community's freedom of action, but they also dilute the threat of punishment. It would not be surprising if potential violators interpreted such vagueness as a lack of will to act against wrongdoers.

Historical experience could easily reinforce such a perception. With the exception of post-Gulf War Iraq, most other recent examples of treaty enforcement decision making

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57 Few developing countries use expensive, sophisticated mine types; a state wishing to reduce the distinctiveness of its minelaying would thus not be driven to unusually expensive mines. Similarly, a state wishing to reduce visible differences between earlier, legal minelaying and later, illegal use would tend to forgo modernization with more sophisticated, and possibly more expensive, designs.

58 For example, the UN Landmine Protocol: see UNCCW text, reprinted in Human Rights Watch, *Deadly Legacy*, pp. 365–80. Note, however, that an absence of enforcement provisions need not prevent individual state parties from imposing unilateral sanctions on violators. The U.S. government, for example, has proposed to deny landmine exports unilaterally to states found in violation of the UNCCW: See Office of the Press Secretary, The White House, "Fact Sheet: U.S. Policy on a Landmine Control Regime," Press Release, 26 September 1994.

59 For example, the Nuclear Non-Proliferation Treaty, or the Chemical Weapons Convention: see "Convention on the Prohibition of the Development, Production, Stockpiling, and Use of Chemical Weapons and on their Destruction," Conference on Disarmament, January 1993; "Treaty on the Non-Proliferation of Nuclear Weapons," London, Washington, and Moscow, 1 July 1969. By contrast, in bilateral arms control the threat to withdraw from the treaty if the other side violates its terms provides an explicit, relatively credible sanction threat largely unavailable in a multilateral—or especially humanitarian—context.

have sent mixed signals at best.[60] In the mid-1980s, for example, both Iraq and Iran used chemical weapons in violation of the 1925 Geneva Gas Protocol, but no sanctions were imposed.[61] The Soviet biological weapons accident at Sverdlovsk; the alleged use of mycotoxins ("Yellow Rain") in Laos, Kampuchea, and Afghanistan; and the Soviet missile defense radar at Krasnoyarsk were all held by U.S. officials to be violations of major arms control treaties. All triggered acrimonious debates but little actual enforcement activity.[62] Allegations of North Korean NPT violation produced a strong international reaction in 1994, though the result to date has not been punitive.[63] Alternatively, the result of the recent review conference on the U.N. Landmine protocol provides a more focused case study: its unwillingness to add enforcement provisions to the UNCCW could easily be interpreted as evidence that the international community lacks the will to act against landmine abusers in particular.[64]

The second problem concerns the tension between enforcement and participation. Treaties cannot ordinarily be enforced against states that are not party to them.[65] Potential

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60 In the case of Iraq, NPT violations were identified, and sanctions were invoked, but the proximate cause of international sanctions was the Iraqis' invasion of Kuwait, not their violation of the NPT. Whether the latter would have induced sanctions in the absence of the former (even if the latter had been discovered without the access granted as a result of Iraqi defeat in the war) is far from clear.

61 On chemical weapon use in the Iran-Iraq War, see, e.g., Anthony H. Cordesman and Abraham R. Wagner, *The Lessons of Modern War, Volume II: The Iran-Iraq War* (Boulder, CO: Westview Press, 1990), e.g. pp. 370–72, 506–15; Utgoff, pp. 80–86. For Iraq's and Iran's membership in the Geneva Protocol, see *Arms Control and Disarmament Agreements* (Washington, D.C.: U.S. Arms Control and Disarmament Agency, 1980 ed.), p. 16.

62 On Sverdlovsk, see Utgoff, pp. 120–25; Valerie Adams, *Chemical Warfare, Chemical Disarmament* (Bloomington, IN: Indiana Univ. Press, 1990), pp. 105–10. On Yellow Rain, see Utgoff, pp. 76–80; Adams, pp. 91–105. On Krasnoyarsk, see James Schear, "Arms Control Treaty Compliance: Building Up to a Breakdown?" *International Security*, Fall 1985 (Vol. 10, No. 2), pp. 141–82. Note that much of the debate surrounding each episode concerned disputes over the validity of the allegations (although in several of these cases, such as Sverdlovsk or Krasnoyarsk, violation was eventually proved unambiguously). It is to be expected that such disputes will accompany any likely enforcement initiative, regardless of its merits.

63 See "Agreed Framework Between the United States of America and the Democratic People's Republic of Korea," Geneva, 21 October 1994 as reprinted in *Arms Control Reporter*, 1994, pp. 457.D.23ff.

64 It has been argued that the conference's failure did not result from a lack of will to punish landmine abusers, but rather from concerns by a handful of states that enforcement provisions would violate their sovereignty: personal communication, Stephen Goose, Human Rights Watch, 5 April 1996. But sanctions enforcement often poses problems of conflicting aims and concerns among the participant states. For sanctions to be invoked thus often requires that states be prepared to override other concerns (e.g., regarding erosion of the principle of state sovereignty) in the interest of punishing a transgressor state. The fact that the review conference failed to do so is thus grounds for some degree of concern regarding the international community's will to place landmine enforcement above other considerations that might interfere with sanctions application in the future. On the UNCCW review conference generally, see "Chronology, 1995: The 1995 Inhumane Weapons Review Conference," *Arms Control Reporter*, 1995, pp. 860-3.5 to 860-3.7.

65 See, e.g., Oppenheim, *International Law*, pp. 925–28.

violators thus have an incentive to remain outside the treaty, and beyond the reach of its enforcement provisions. In fact, many (if not all) states apparently act on this incentive: most countries suspected of covert nuclear weapons development, for example, have not joined the NPT.[66] And the more severe, or the more credible, the treaty's enforcement provisions, the greater the disincentive for potential violators to join. Sanction credibility thus tends to counterbalance breadth of participation; this tends to limit the net costs that sanctions can be expected to impose on mine users.[67]

Finally, insurgent or other subnational groups are typically not subject to treaty sanctions. Many such groups lack targetable assets, such as international trade or legal weapon imports, for sanctions to affect. And while treaty obligations are nominally national responsibilities, insurgents are by definition largely beyond the enforcement power of the states with whom they are at war; if states could enforce their laws against insurgents, there would be few insurgencies in the first place.[68] Subnational groups are, however, major users of AP landmines—internal warfare involving insurgent mine use is perhaps the main cause of civilian landmine injuries in the developing world. Hence, even if all U.N. member states were party to a landmine ban, and even if severe sanctions were otherwise credible, an important class of mine users would still be largely exempt from sanctions costs.

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66 Iraq is a notable exception. For NPT membership, see *Arms Control and Disarmament Agreements*, pp. 95–98.

67 Enforcement by positive inducement could, in principle, escape this dilemma. By providing demining assistance in exchange for compliance with a minelaying ban, for example, a treaty might entice compliance by states that would ignore a punitive treaty. This approach, however, requires a credible commitment to provide the benefits to all states that comply. Other things being equal, the more attractive the benefit—and thus the more powerful the inducement to compliance—the more expensive this commitment becomes, and the greater the likelihood that the international community would fail to make good on its promises. In particular, the most natural form of positive inducement for landmine treaty compliance, demining assistance, is chronically underfunded relative to the needs of such a treaty regime. The U.N.'s entire demining budget is now only $28 million a year, which provides only a fraction of the effort that would be needed to offer meaningful assistance to any mined state that might comply with a future treaty; efforts to increase this funding have made limited headway in the face of national fiscal constraints: Blagden interview.

68 Note that this would not preclude, for example, the extension of the UNCCW to cover internal warfare, but such an extension would effectively bind only government use of mines in internal warfare.
On the treaty obligations of insurgents or other subnational groups, see, e.g., Oppenheim, *International Law*, pp. 366–69. Note that an emerging international legal theory implies greater subnational treaty obligation than the older view represented by Oppenheim: see Michael Bothe, Karl Josef Partsch, and Waldemar A. Solf, *New Rules for Armed Conflicts: Commentary on the Two 1977 Protocols Additional to the Geneva Conventions of 1949* (The Hague: Martinus Nijhoff Publishers, 1982), e.g. pp. 7–10, 39–43, 46–52, 604–8, 622–29. Regardless of their formal legal standing, however, in practical terms such groups are largely beyond the reach of treaty sanction provisions.

Some optimistic assumptions are thus required for sanctions to impose a large cost on landmine users. One must posit both the international political will to carry out harsh punitive sanctions, and participation by violators in the treaty regime that imposes those sanctions. It is at least plausible that one or both of these conditions could fail to obtain.

3. Net Costs of Arms Control for Landmine Users

How, then, do evasion and sanction costs combine? For most treaty types, monitoring can be evaded with reasonable, though imperfect, effectiveness. A ban on landmine use would probably be hardest to evade, though evasive efforts per se would be inexpensive if attempted. Sanctions costs thus matter, since violations will eventually be discovered for any treaty type, but sanctions may be discounted fairly heavily by potential violators (given low odds of discovery in any given year).

Given this, we can provide at least a crude upper bound on the cost increase arms control might impose on landmine users.[69] For the purposes of illustration, let us assume a total ban on AP mine production, export, stockpiling, and use, and one that included most developed countries and at least some developing states.

For a nonsignatory, the cost of mine use under such conditions would rise at most to the cost of domestic hand manufacture of the needed mines—or perhaps three times that of the cheapest mines available today. Such production could not be prevented by removing high-volume exporters located in treaty member states, and a nonsignatory would be free to stockpile and use whatever mines were available to it. Of course, this figure is only an upper bound; the actual cost increase could be significantly smaller if, for example, manufacturers in states outside the ban provided mass-produced mines at lower cost than hand assembled versions.

For illegal use by a state party to the treaty, upper bound costs would be somewhat higher than for a nonsignatory (reflecting mostly the additional cost of sanctions resulting from eventual discovery of illegal minelaying), but are unlikely to be much higher. Again, however, if mass producers continued to operate in states outside the ban, or if the treaty's

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[69] A potential exception would be a treaty combining credible, attractive inducements for compliance with a ban on mine use. Violation of a use ban would be difficult to conceal, and loss of the inducements would provide a substantial opportunity cost to violators without discouraging states from signing the treaty. The net result could be a significant increase in the effective costs of mine use by states party to the treaty, and a reasonable likelihood of widespread state participation. Such a regime would commit the international community to an expensive program of long-term compliance inducement, however, and the credibility of such a commitment in the face of inevitable fiscal pressures is far from clear.

sanctions were modest or lacking in credibility, the actual cost increase could be significantly smaller.[70]

B. COST ELASTICITY OF LANDMINE USE

Are cost increases of this magnitude likely to cause a large reduction in mine use? While a quantitative answer will not be possible, there are qualitative theoretical and empirical reasons to expect landmine use to display relatively low cost elasticity. This in turn suggests that for landmines, a large cost increase would probably be necessary to produce a large near-term reduction in use.

1. Landmine Cost Elasticity in Theory

The cost elasticity of a good is determined mostly by the availability of substitutes, secondarily by the fraction of the consumer's total income devoted to the good, and partly by the time horizon of the estimate. Each is positively correlated with cost elasticity (i.e., the greater the availability of substitutes, or the higher the income fraction, or the longer the time horizon, the more elastic the demand is likely to be).[71] For landmines in the developing world, substitute availability and income fractions are likely to be low, while, as for time horizon, one would at least prefer that controls change behavior relatively quickly. Landmines can thus probably be expected to exhibit low cost elasticity, at least in the near to mid term.

Substitute availability, for example, is likely to be low for developing countries, and especially by comparison with industrialized states. This is because third world armies tend to be undercapitalized and are often poorly trained or educated; for these conditions, landmines are ideal. They require little instruction to operate, and are simple enough for poorly educated soldiers to use. They can be effective without requiring face-to-face contact with the enemy, and are thus well suited to poorly disciplined or ill-motivated troops. They require no extensive infrastructure for repair, maintenance, or refueling, and are thus well suited to the austere logistical systems of most third world militaries. Moreover, they are radically cheaper than most other weapon types. For the price of a

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70 Note that these costs are expressed in financial terms to reflect the primary drivers identified in the discussion above. Non-financial costs of evading arms control monitoring (e.g., inefficient resource distribution as a result of a more dispersed stockpile), while non-zero, are likely to be low: see discussion above. Of course, to ignore an international treaty or to use weapons associated with an international stigma could involve political costs as well; to assess these, however, is a task beyond the scope of this analysis.

71 See, e.g., Edwin Mansfield, *Microeconomics*, fourth edition (New York: W.W. Norton and Co., 1982), pp. 116–17.

single obsolescent tank, tens of thousands of landmines could be purchased—and the mines do not require the maintenance system, crew training, or fuel and ammunition resupply the tank would need.[72] Even if mine costs were doubled or tripled they would still be far less expensive than most alternatives—and far easier to use. Few substitutes are nearly so well adapted to the needs of developing world armies.[73]

Alternatively, the fraction of developing world defense expenditure devoted to landmine acquisition is very low. Global AP landmine production has been estimated to total some $50 to $200 million annually.[74] If we conservatively assume that three-fourths of this amount is spent by developing countries, then perhaps $40 to $150 million a year is spent on AP landmines in the third world. Total defense spending by developing countries outside the Middle East was about $71 billion a year in 1994.[75] The developing world thus probably spends less than two-tenths of one percent of its annual military budget on AP mines.[76] By way of comparison, a two-car family with an after-tax income of $40,000 a

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72 A used ex-Russian T72 tank, for example, would cost more than $350,000 on the current international market (not including crew training, spare parts, tools and repair equipment, recovery vehicles, ammunition, fuel, or lubricants): Christopher Foss, "BMP-3 on the Open Market," *Jane's Defense Weekly*, 16 January 1993, p. 19. For the price of the vehicle alone, more than 100,000 $3 landmines could be purchased; even if arms control raised landmine costs by a factor of two, mines could still be acquired at the rate of more than 50,000 for every tank—and the mines, unlike the tank, require little or no support system for effective use. Even such simple alternatives as rifles are still much more expensive than mines; a single Russian AK47 costs some $200, or about as much as 60 to 70 Chinese AP mines: see Mark Galeotti, "The Russian Arms Bazaar," *Jane's Intelligence Review*, November 1992, p. 491.

73 For similar arguments, see Richard H. Johnson, "Why Mines? A Military Perspective," in Cahill, pp. 24–44, esp. pp. 33–4.
Note, however, that while few substitutes are available for landmines as a class of weapon, substitutes for individual mine models are readily available. Brazilian scatterable mines are easily substituted for Italian; metal mines can be substituted for plastic designs; homemade mines can be substituted for manufactured ones. The international market for any given manufacturer's product is thus likely to be highly price-elastic (which tends to hold down the market price) even though the demand for mines per se is likely to be substantially inelastic.
Note also that the analysis above is not intended to provide a complete assessment of the military utility of landmines for developing world armies. To do this would require a marginal analysis of the effects of adding or subtracting mines from third world forces, with sensitivity analyses to account for variations in terrain, tactics, or other local conditions (for an example of such an analysis performed for a developed-world army in high intensity combat, see Stephen Biddle, Julia Klare, and Jason Rosenfeld, *The Military Utility of Landmines: Implications for Arms Control*, IDA Document D-1559, Institute for Defense Analyses, Alexandria, VA, 1994). Such a complete assessment is beyond the scope of this paper. Instead, the analysis above is intended to address the narrower question of substitute availability and cost in terms pertinent to elasticity theory.

74 Human Rights Watch, *Deadly Legacy*, p. 36.

75 International Institute for Strategic Studies, *The Military Balance, 1995/96* (London: Oxford Univ. Press, 1995), pp. 264–269; the figure above was obtained by subtracting the defense budgets of NATO, Russia, China, Japan, Austria, Ireland, Sweden, Switzerland, Finland, Australia, New Zealand, Taiwan, South Korea, and the Middle East from the global total.

76 Note that this estimate excludes the broader social costs of mine use (e.g., demining, treatment for mine victims, or economic output lost from non-use of mined land) that may be associated with a

year spends a larger fraction of its budget on oil changes.[77] Even a large percentage increase in mine costs is thus unlikely to consume a large fraction of developing world defense expenditure; feasible cost increases can be made up by relatively modest reallocations of resources.

As for time horizons, cost elasticity is usually higher in the long run than the short.[78] This implies that to obtain a large near-term reduction in mine use would require a particularly large increase in cost. Alternatively, it suggests that to obtain a large reduction in use from a modest cost increase could require considerable patience.

2. Empirical Evidence

Too little is known about historical mine price and consumption relationships to provide a systematic empirical analysis. But what *is* known, though unsystematic, is suggestive, and tends to support the theoretical indications above.

In particular, Salvadoran mine use is highly instructive. Few armies in recent years have lacked ready sources of cheap, mass-manufactured mines. Salvadoran insurgents in the mid-1980s, however, failed to obtain access to imported mines. Rather than forgo mine use, they chose to manufacture indigenous mines by hand in significant numbers without specialized facilities.[79] As noted above, this form of production approximates the maximum cost that arms control can impose on mine users. Yet the cost did not suffice to halt large-scale mine use by a developing world army.[80]

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state's decision to purchase mines. While it might be preferable for mine-using states to approach mine use decision making in light of such a broader definition of cost, there is little evidence to date that such a definition is widely used, or that it would come to be so in the event of a treaty. We thus focus here on direct budget outlays for mine acquisition.

77 Assuming an average annual mileage of 15,000, one oil change per 3,000 miles, and a cost of $25 per oil change.

78 In part because better substitutes eventually are brought to market, and in part because a longer time frame makes any given substitution easier to accommodate: Mansfield, p. 117.

79 Jean-Pierre interview; Blagden interview; Reeder interview; Human Rights Watch, *Landmines in El Salvador and Nicaragua*, pp. 23–27, 39–41.

80 Similarly, in the Vietnam War the Viet Cong and North Vietnamese forces made extensive use of hand-made booby traps and field expedient mines (often fashioned from unexploded U.S. ordnance found on the battlefield) to supplement mass-manufactured imported mines, even though their access to the latter was relatively easy: see, e.g., U.S. Department of the Army, *TC 5-31*, pp. 5-2 to 5-3; U.S. Marine Corps, *Professional Knowledge Gained*, pp. 267–69.

Unfortunately, the data is thin (in part because cheap imported mines have been so widely available); but what little we do know tends to corroborate a theoretical prediction of low cost elasticity of use for landmines. Given this, it is far from clear that attainable cost increases will produce reductions in mine use as large as those often claimed in the public debate.

IV. DISADVANTAGES OF LANDMINE CONTROLS

The main potential disadvantage of landmine controls from a U.S. perspective is their effect on U.S. military capability. Opponents of such controls have suggested that this effect could be very large. The U.S. Army, for example, has argued that landmine use can be expected to cut American combat losses roughly in half, and to improve loss-exchange ratios by a factor of two.[81]

As is true of most weapons, however, the military effects of landmines depend on the circumstances of their use, such as the types of mines used; the numerical balance of forces; terrain; tactics; or the type of contingency, such as the difference between major regional contingencies (MRCs) and low-intensity conflict, or operations other than war (OOTW). And the military effects of a landmine treaty are sensitive to all of these factors, plus the treaty's likely adherence rate—as reflected both by the number of state parties and by the willingness of those parties to violate the treaty's terms.[82]

As a function of such circumstances, landmines' military effects can vary enormously. Our analysis suggests that for some combinations of these conditions, landmine controls could produce a factor-of-two effect on U.S. losses, as opponents argue. For other conditions, however, the military effects of controls could be much smaller, and it is far from clear that the former are either more or less likely than the latter.

To show why, we will focus on the effects of just three of these variables: the balance of tactical offense and tactical defense, the types of mines in use, and the adherence rate of a putative treaty.

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81 Headquarters, Department of the Army, *Information Paper: Landmine Arms Control*, 8 June 1994, p. 1. See also "Army Protests Pending Congressional Action on Landmine Moratorium: Mine Warfare 'Key Combat Capability'," *Inside the Army*, 13 June 1994, pp. 8–9.

82 For the purposes of this analysis, we will assume that the United States joins any putative treaty. If it joins, the United States will comply with its terms. Potential opponents, however, may not join, and even if they do, they may or may not comply.

A. THE BALANCE OF TACTICAL OFFENSE AND DEFENSE

Most military actions involve a mix of tactical offense and tactical defense for both combatants.[83] Invaders conduct tactical assaults at chosen points of main effort, but typically defend elsewhere; armies resisting invasion typically defend tactically at the attacker's point of main effort, but often counterattack at or away from that point.[84] The particular balance of the two can vary widely for any given army as a function of strategic circumstances. The U.S. Army, for example, fought mostly—but not exclusively—on the tactical defensive in the opening weeks of the Korean War, then switched to primarily offensive actions following the Inchon Landing, then reverted to mostly defensive fighting in the weeks after the Chinese entered the war in November 1950.[85] The U.S. Marine Corps was mostly on the tactical offense in the Persian Gulf War of 1991, but fought tactically defensive actions against Iraqi counterattacks at Khafji on January 29, or at the Burqan Oilfield on February 25.[86] The particular balance for any given future campaign can be very difficult to predict: the U.S. Army that fought primarily on the tactical offensive in the Gulf, for example, was designed for a European war that most planners expected to involve at least as much tactical defense as offense.[87]

The mix that emerges, however, can strongly influence the net military utility of landmines for either combatant. This is because mines affect tactical attackers and defenders differently. For tactical defenders, mines can provide economy of force, canalize attacks, and of course, destroy attacking vehicles and kill or wound attacking

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83 Military operations are often described on three levels. The *tactical level* concerns the activities of small subunits (e.g. companies and battalions), the *theater strategic level* concerns the activities of armies and army groups, and the *operational level* pertains to the echelons in between (e.g., brigades, divisions and corps): see, e.g., John I. Alger, *Definitions and Doctrine of the Military Art* (Wayne, NJ: Avery Publishing Co. for the U.S. Military Academy, 1985), p. 5. On the heterogeneity of offense and defense in theater warfare, see Stephen Biddle, "Offense, Defense, and the End of the Cold War: Criteria for an Appropriate Balance," *Defense Analysis*, Vol. 11, No. 1, 1995, pp. 65–74; idem., *The Determinants of Offensiveness and Defensiveness in Conventional Land Warfare* (Harvard University, 1992), pp. 61–67; Jonathan Shimshoni, "Technology, Military Advantage, and World War I," *International Security*, Winter 1990/91 (Vol. 15, No. 3), pp. 187–215.

84 For a more complete discussion, see Biddle, *Determinants*, pp. 61–67.

85 See, e.g., Roy Appleman, *The United States Army in the Korean War: South to the Naktong, North to the Yalu* (Washington, D.C.: Office of the Chief of Military History, Dept. of the Army, 1961).

86 See, e.g., Michael Gordon and Bernard Trainor, *The Generals' War* (Boston: Little, Brown and Co., 1995), pp. 267–288, 363–69.

87 See, e.g., BG Robert Scales, Jr., *Certain Victory: The U.S. Army in the Gulf War* (Washington, D.C.: Office of the Chief of Staff, U.S. Army, 1993), pp. 6–38.

soldiers.[88] For tactical attackers, artillery or air-delivered scatterable mines are more often used to defend flanks against defensive counterattacks, or to pin defenders in place to prevent their movement or withdrawal.[89]

To evaluate the net effects of these differing uses, a series of combat simulation analyses were conducted. In particular, four scenarios were considered.[90] All four involved heavy brigade-size U.S. defenses which were attacked by a Soviet-type opposition force (OPFOR) tank division on a desert terrain sample taken from the U.S. Army's National Training Center at Ft. Irwin, California.

In two of these, the U.S. defenders were supported by very extensive landmine deployments containing a mixture of antipersonnel (AP) and antitank (AT) mines, and equivalent to some 85 engineer platoon hours of effort, while the OPFOR were given six battery volleys of scatterable artillery-delivered AT/AP mines to be used for flank defense. In the other two scenarios, all mines were removed from both sides.

Of the two extensively mined cases, one involved a pure tactical defense by the U.S. brigade, while the other used one of the brigade's two battalions in a tactically offensive counterattack into the flank of the OPFOR assault. Similarly, the two no-mine-use cases were constructed with one purely defensive action by the U.S. brigade, and one with a combination of tactical defense and counterattack as considered in the heavy-mine-use cases. The resulting four scenarios thus provide a controlled comparison of the effects of landmine use as a function of variations in the mix of tactical offense and defense within a U.S. brigade.

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88 Landmines provide *economy of force* by enabling positions to be held by smaller units, permitting commanders to use available resources more efficiently. Mines *canalize attacks* by reducing the amount of usable terrain, forcing attackers to reduce frontages, to stack assault forces in successive echelons and commit them to battle piecemeal, and to direct attacks into prepared engagement areas where defensive weapons can be sited for maximum effect. Mines increase attackers' losses in two ways. They inflict direct damage on attackers that detonate mines. But they also cause damage indirectly by diverting attackers into disadvantageous locations, and by inducing them to slow down in the presence of enemy fire to remove mines from their path. The attacker is thus exposed to defensive fire longer, and at longer ranges (where defenders are typically at greatest relative advantage). As a result, landmines reduce a defender's losses.

89 Scatterable mines can also be employed as part of counterbattery artillery fires (to pin opposing artillery in place) by either tactical defenders or attackers, or at the operational level by using them as part of a deep battle program to hamper enemy movement in the rear, though these modes of employment have played a limited role in the arms control debate to date. For an assessment of the effects of such use, see Stephen Biddle, D. Sean Barnett and David G. Gray, *Stabilizing and Destabilizing Conventional Weapons*, IDA Paper P-2548, Institute for Defense Analyses, Alexandria, VA, 1991, pp. A-10 to A-13,.

90 For a more detailed discussion of the scenarios used and the results obtained, see Biddle, et al., *Military Utility*, pp. 28–35.

The results are presented in Table IV-1 and Figure IV-1.

Table IV-1. U.S. Combat Vehicle Losses as a Function of Mine Use and Tactical Offense-Defense Mix

	U.S. Vehicle Losses*	
	Mines Used	No Mines Used
Pure tactical defense	40.0 [9.1]	67.2 [7.2]
Tactical defense/offense mix	74.8 [9.0]	92.5 [10.9]

* Entries provide mean U.S. losses for 15 simulation repetitions; figures in brackets are associated standard errors.

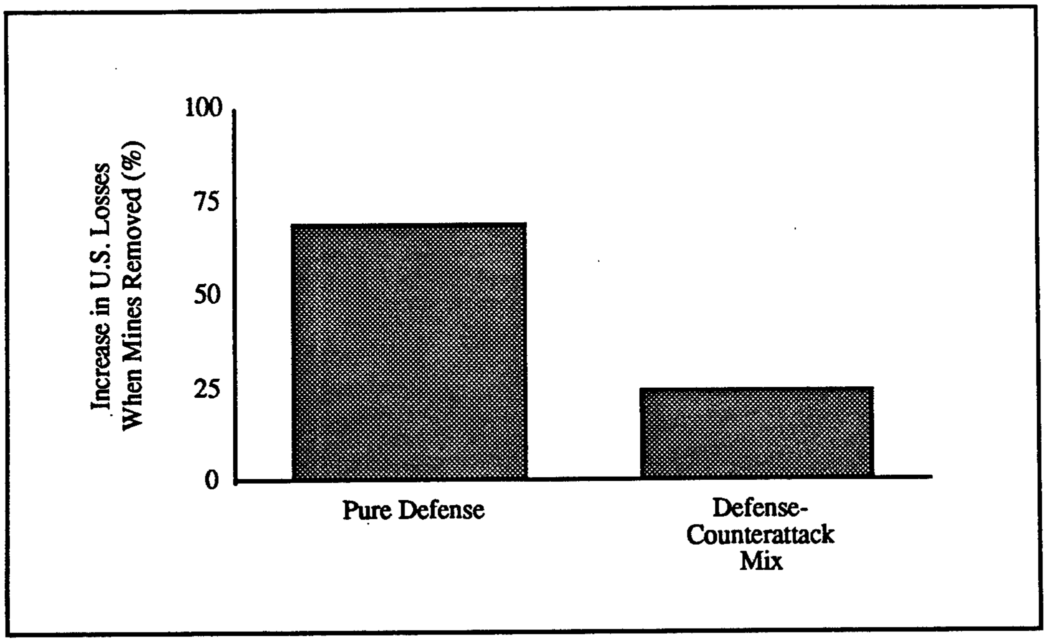

Figure IV-1. Effect of Tactical Offense-Defense Mix

These results suggest that the balance of tactical offense and defense can have a significant effect on the military utility of landmines. For the pure tactical defense scenarios, removing all landmines on both sides caused about a 70 percent increase in U.S. losses; when the U.S. brigade combined tactical defense and counterattack, however, removing landmines increased U.S. losses by about 25 percent.[91]

91 OPFOR/U.S. combat vehicle loss exchange ratios (LERs) were 3.47 for the pure tactical defense with mines case; 1.92 for the pure defense with no mines case; 1.83 for the mixed US offense-defense with mines case; and 1.47 for the mixed US offense-defense without mines case. Like U.S. losses per se, loss exchange ratios thus worsened by nearly a factor of two for the pure tactical defense case when landmines were removed, but by far less when a mix of tactical offense and defense was considered.

This difference is because of the way such tactical variations alter the two sides' exposure to hostile mines. In the pure defense case, for example, the OPFOR is exposed to the full weight of U.S. minelaying. U.S. forces, however, provide no targets for OPFOR mines: without a U.S. counterattack, the OPFOR's ability to use scatterable mines to defend its flank is moot, and since the U.S. defense consistently held in these runs, there was no U.S. retreat to be interdicted. Mines thus work solely to U.S. benefit, and the effects of removing them are one-sided and large.

In the mixed tactical defense and counterattack case, on the other hand, the U.S. counterattack battalion strikes the artillery-delivered minefield protecting the OPFOR flank. Now both sides are exposed to hostile mines; hence, both sides obtain some advantage and suffer some losses as a result of minelaying. When all mines are removed, the effect is thus no longer one-sided: the U.S. suffers from the loss of the mines protecting the strongpoint battalion, but it benefits from the loss of the mines protecting the OPFOR flank. While the effects do not completely cancel (the net result is still an increase in U.S. losses when the mines are removed), the magnitude of the increase is much smaller than in the pure defense case.[92]

B. THE EFFECTS OF MINE TYPE AND TERRAIN

1. Antipersonnel vice Antitank Mines

Most landmine cost-effectiveness analyses assume a mix of AP and AT mines.[93] The arms control debate, on the other hand, focuses primarily on AP. The military effects of the two, however, are not necessarily the same.

In particular, joint variations in mine type and terrain can produce very different military outcomes. AP mines, for example, are designed for use against dismounted troops and are ineffective against heavy vehicles; rough terrain, which promotes the use of dismounted infantry in the assault, thus tends to provide more targets for AP mines than does open terrain, in which all-mounted attacks are more common. AT mines are the other way around. Designed for use against heavy vehicles and ineffective against dismounted

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92 For similar arguments, see, e.g., Johnson, p. 33.

93 See, e.g., H.A. Freeberg and W.L. Fuller, *Countermobility in Support of AirLand Battle Study: Combat Power of Minefields* (Ft. Leavenworth, KS: TRADOC Analysis Command, September 1992), TRAC-WSMR-TR-90-004; Department of the Army, United States Training and Doctrine Command Systems Analysis Activity, *Effects of Barriers in a Combat Environment* (White Sands, NM: TRASANA, 1978), as referenced in U.S. Army Corps of Engineers, Engineer Studies Center, *Survivability—The Effort and the Payoff*, R-81-8, June 1981.

infantry, they are thus better suited to the all-mounted attacks that occur more often in open terrain.[94] The relative contributions of the two mine types will thus vary as a function of terrain and the relative importance of mounted and dismounted operations.

As an illustration of the potential magnitude of such variations, a second series of simulation analyses were performed. While the first series assumed a mounted attack over open terrain, the second series considered a partially dismounted assault conducted on rough, heavily wooded ground just south of the Korean Demilitarized Zone. Two scenarios were considered. In each, a U.S. mechanized battalion fought a pure tactical defense against a Soviet-style OPFOR tank regiment. The OPFOR attack was organized with two battalions advancing on each of two converging axes: the first of these, running along a forested slope leading toward the U.S. right flank, was assigned two dismounted motorized rifle battalions; the other, following the most trafficable terrain into the heart of the U.S. position, was assigned two tank battalions. The OPFOR assault was timed for the two elements to arrive simultaneously on the U.S. position.[95]

The two scenarios differed in their respective landmine deployments. In the first, the U.S. defense was supported by an extensive system of minefields with AP and AT mines in roughly equal proportion; in the other, all U.S. AP mines were removed, but all AT mines were retained (no OPFOR mines were considered).

The results are presented in Table IV-2. They suggest, first, that AP mines in close terrain, like the AT mines considered above, have positive military utility for defenders—when they are removed, the defender's losses increase. The magnitude of the increases, however, can be very different. Whereas losses in the open terrain, pure defense case increased by more than 70 percent when all landmines were removed, losses here increase by only about 10 percent when AP mines are removed from a pure defense fought in close terrain.

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94 On the relationship between terrain and dismounted infantry use, see, e.g., *FM 71-3: Armored and Mechanized Infantry Brigade* (Washington, D.C.: Headquarters, Department of the Army, 1988), pp. A-1, A-3.

95 Note that the terrain, force dispositions, and OPFOR plan of attack were selected to provide conditions promoting extensive dismounted combat, and thus to highlight the potential utility of antipersonnel mines, rather than to provide a typical or generally representative scenario per se. For a more detailed description, see Biddle, et al., *Military Utility*, pp. 36–39.

Table IV-2. U.S. Combat Vehicle Losses as a Function of U.S. Antipersonnel Mine Availability

	U.S. Losses*
Pure tactical defense, rough terrain: AP and AT landmines used	48.9 [8.3]
Pure tactical defense, rough terrain: All AP mines removed	55.2 [11.1]

* Entries provide mean U.S. vehicle losses for 15 simulation repetitions; figures in brackets are associated standard errors.

The increase in mine losses is smaller here, partly because AP mines affect only a part of the OPFOR force here (the two dismounted battalions), whereas in the all-mounted desert case the mines that were removed affected all OPFOR targets. But it is also due to the more vulnerable nature of the AP mines' targets in these runs. Even without AP mines, the defenders' other weapons took a heavy toll on the OPFOR's dismounted infantry. While the infantry assault did better when the mines were removed (the defenders' losses did increase), the attackers' heavy losses to the defenders' other weapons caused the attack to stall after only a small additional gain (and thus a small additional effect on U.S. losses). The OPFOR's tanks, by contrast, were vulnerable to a narrower range of the defenders' other weapons; the AT mines in either scenario thus provided a form of firepower that was in relatively shorter supply.[96] The net result was a significant variation in landmine contribution to the defense as a whole, as a function of differences in terrain and mine type.

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96 Note that infantry is not an inherently inferior offensive weapon. Its strengths and weaknesses in this role, however, are relatively less susceptible to mine warfare than are tanks'. Tanks' unique strengths are their organic armor protection, speed, and firepower, which together enable them to close directly with the enemy and overcome defenses by shock effect. Tanks' weaknesses include their crews' poor visibility and the difficulty of concealing them from enemy observation in the assault. These strengths and weaknesses make them especially susceptible to landmines relative to other weapons. AT mines strike tanks where their armor is weakest (the tracks and belly); thus mines provide unusual antitank lethality for their weight and size. Well-positioned minefields inevitably slow and often disorganize attacks; shock effects require speed and concentration, and are thus unusually susceptible to the disruption and delay characteristic of mine use. By canalizing and slowing attacks, mines can significantly reduce the effectiveness of tanks' fire—for example by holding them at long range (where defenders typically enjoy a target acquisition advantage) or by redirecting them into areas affording greater concealment for defenders. And landmines' small size makes them especially hard for tank crews to see and avoid, while tanks' large size makes it harder for the attacker to hide from enemy fire while the mines are cleared.

By contrast, dismounted infantry's unique strengths in the attack are its superior stealthiness, sensory acuity, and rough terrain mobility, while its weaknesses include its lack of armor protection, heavy firepower, or high speed. These properties certainly do not make infantry attacks invulnerable to mine warfare, but they tend to mitigate the impact of mines compared with tanks. Minefields can often be detected and cleared or avoided by attackers willing to take the time needed for careful reconnaissance and/or circuitous advance to take advantage of gaps in mine coverage. For a tank attack dependent on speed for success, this is often problematic. For an infantry attack relying more on stealth than on speed, this is more easily accommodated. Dismounted infantry are also better at detecting mines than are vehicle crews, whose view of the ground is limited and whose higher speeds provide less time for

2. Self-Deactivating vice Non-Self-Deactivating Mines

A second distinction of importance for arms control is between self-destructing (SD), self-deactivating (SDA), and non-self-destructing (NSD) mines.[97] Most modern U.S. mines contain some mechanism for self-deactivation after deployment.[98] This is intended mainly to facilitate friendly maneuver after the use of artillery or air delivered scatterable mines, but it also tends to reduce the humanitarian hazards associated with mine warfare.[99]

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inspection. Dismounted infantry's lower profile, quieter movement, and superior ability to operate under low visibility conditions reduces its exposure to fire while doing so. While defenders sometimes use AP minefields to provide warning of dismounted approach, minefields not under direct observation are vulnerable to covert clearance by well-trained dismounted attackers (North Vietnamese and Viet Cong sappers were especially adept at covert mine removal: Eric Bergerud, for example, quotes one platoon leader in A Company, 2nd Battalion, 27th Infantry to the effect that "[the VC] were tremendously inventive . . . . We never put out antipersonnel mines—we knew they would be dug up and used against us. Claymores were strictly accounted for, but they were still stolen." Eric Bergerud, *The Dynamics of Defeat: The Vietnam War in Hau Nghia Province* (Boulder: Westview Press, 1991), p. 229). Finally, while tanks' thin belly armor makes them unusually vulnerable to mines relative to other defensive weapons, thin-skinned infantry are no more or less vulnerable to mines' blast or fragmentation effects than they are to any other weapon on the battlefield.

Of course, none of this is intended to suggest that AP mines are ineffective against dismounted infantry; on the contrary, the analytic results above show increased defender losses against dismounted attack when AP mines were removed. Rather, it is meant to suggest that *the marginal contribution of AP mines to defense against dismounted attack will often be smaller* than the marginal contribution of AT mines to defense against mounted assaults, both because dismounted infantry is often relatively less vulnerable to mine warfare than are tanks, and because dismounted infantry is often relatively more vulnerable to non-mine defensive weapons than are tanks. (Note, however, that these observations pertain to well-trained, disciplined light infantry operations. Against poorly trained or poorly employed infantry, AP mines can be expected to be more effective, both in absolute terms and relative to AT mines or other defensive weapons).

97 *Self-deactivating* mines are designed to become inert after a predetermined time. *Self-destructing* mines detonate, rather than becoming passively inert, after a predetermined time.

98 See, e.g., *Jane's*, pp. 244–50.

99 While SD/SDA mines would clearly produce fewer civilian injuries and less economic damage than NSD mines, the *magnitude* of the difference is difficult to project. First, the reliability of SD mechanisms will surely vary from nation to nation and manufacturer to manufacturer, and will probably vary as a function of use and environmental conditions as well. (SDA mechanisms relying on battery run-down to render the mine inert, on the other hand, are more uniformly reliable.) Monitoring to ensure adequate self-destruct reliability for any given mine stockpile in any given location could be very difficult. Ground sown with SD mines may thus still require demining before it can be returned to civilian use, depending on the actual field performance of a wide range of international mine designs under a wide range of local conditions. Second, even successful self-deactivation (vice self-destruction) would leave inert but apparently functional mines on the ground; it is unclear how these would be positively identified as inert in such a way as to obviate the need for demining (the U.S. Army, for example, treats self-deactivated mines as hazardous duds requiring removal by unexploded ordnance disposal teams: *FM 20-32: Mine/Countermine Operations* (Washington, D.C.: Headquarters, Dept. of the Army, 1992), pp. 6–7).

SD/SDA mines are significantly more expensive than NSD, but in exchange they offer greater military effectiveness.[100] In particular, SD/SDA mines increase battlefield flexibility in two ways. First, they enable rapid minefield creation by making mechanical scattering devices practical. Such systems can sow mines very rapidly: the U.S. Volcano multiple delivery mine system, for example, can create a barrier of 560 by 320 meters containing some 960 mines in less than a minute.[101] This enables commanders to prepare even hastily occupied positions for defense with minimal engineering support. Second, they enable commanders to restrict their opponents' freedom of maneuver without simultaneously limiting their own. SD/SDA scatterable mines make it possible, for example, to use landmines to canalize an assault into a prepared engagement area, then counterattack into that engagement area from a flank without risking destruction by one's own mines.

A landmine arms control regime banning NSD mines would thus not necessarily reduce the effectiveness of U.S. forces.[102] In fact, under some conditions an NSD mine ban could improve U.S. military performance, in that we are more likely than many potential opponents to be able to afford SD/SDA mines in quantity. An enforceable ban on NSD mines would thus probably affect our opponents to a greater degree than ourselves.

C. THE EFFECTS OF OPPONENTS' NONCOMPLIANCE

The military effects of a treaty would also be influenced by its compliance rate. Not all states will sign any given treaty, and even for states that do, insurgents within their

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100 Price differentials can be as great as a factor of 10 to 60: see, e.g., Parks, p. 55; Human Rights Watch, *Deadly Legacy*, p. 40.

101 Department of the Army, *FM 20-32*, pp. 6-23 to 6-31.

102 An exception concerns the use of NSD mines in static minefields. Static minefields, such as those defending the U.S. military base at Guantanamo Bay Cuba or the Korean Demilitarized Zone, are maintained for extended periods in the same location. Current self-deactivation mechanisms provide relatively short active lifetimes (hours to days) due to limited battery life. To use current SD/SDA mines for such minefields would require prohibitively frequent mine replacement, and as a result, they now contain only NSD mines. Technical improvements permitting longer active lifetimes for SD/SDA mines are possible, such as remotely switched mines which can be turned on or off by radio, and whose fusing electronics operate only when turned on (thus, their batteries would provide longer life). The adequacy or cost-effectiveness of such improvements has not been established, however, and such an analysis is beyond the scope of this paper. Alternatively, NSD requirements for static minefield maintenance could be exempted from a broader ban via special subceilings (although this would complicate monitoring, as noted above). The latter is current U.S. government policy: see Office of the Press Secretary, The White House, "Fact Sheet: U.S. Policy on a Landmine Control Regime," 26 September 1994, p. 1.

borders are largely beyond the states' enforcement powers.[103] And of course, state parties to a treaty might violate its terms. What effect can we expect this to have?

The answer depends on the type of treaty, and the type of conflict. Some treaty types, for example, would have little effect on preferred U.S. mine uses anyway. As noted above, modern U.S. mines are self-destructing/self-deactivating; as we retire older NSD mines in favor of newer SD/SDA designs, our NSD holdings will decline. Thus, a treaty imposing numerical ceilings on NSD mines might eventually have little (or possibly no) effect on U.S. minelaying. Similarly, all current U.S. mines contain at least some metal; a ban on metal-free mines could thus have little effect on U.S. stocks.[104] Even if our opponents ignore such treaties, we are not much worse off than if there were no treaty at all, since our own behavior is largely unaffected.[105] And if violators use fewer mines because a treaty imposes evasion costs, then our military performance could actually improve as a result of such a treaty.

Alternatively, some types of conflict involve little or no U.S. mine use but substantial minelaying by our opponents. In operations other than war (OOTW), for example, U.S. rules of engagement often prohibit friendly minelaying altogether.[106] Yet in Operation RESTORE HOPE in Somalia, U.S. personnel who employed no landmines of their own suffered over 25 percent of their total casualties from mine use by local

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[103] As of 1992, for example, only 35 of the U.N.'s then-179 member states were parties to the U.N. Landmine Protocol (which entered into force on 2 December 1983): Human Rights Watch, *Deadly Legacy*, p. 378.

[104] However, treaties specifying a minimum metal content threshold might or might not affect U.S. mines, depending on the threshold. It has been estimated that an 8-gram minimum metal requirement, for example, could force the modification or destruction of some 4 million U.S. mines: personal communication, Stephen Goose, Human Rights Watch, 4 April 1996. On U.S. AP mine designs, see, e.g., *Jane's*, pp. 244–250.

[105] Note that this assumes that the U.S. maintains proper training and doctrine for responding to such noncompliance in spite of our own observation of its terms. Note also that the discussion below pertains only to the *military* consequences of such violation—the larger issues of the effects of noncompliance on the international rule of law or the norms of state behavior will not be addressed here.

[106] See, e.g., Rules of Engagement of TF Mountain OPLAN 93-2 (Operation RESTORE HOPE), reprinted in Commandant, U.S. Army Infantry School, *The Application of Peace Enforcement Operations at Brigade and Battalion* (Ft. Benning, GA: U.S. Army Infantry School, 31 August 1993), pp. B-4-1 to B-5-2, at B-4-3. In accordance with these rules of engagement, no mines were sown by any U.S. forces in Somalia: telephone interview, CAPT David A. Dawson, Headquarters, U.S. Marine Corps, History and Museums Division. Nor were any U.S. mines employed in Operation PROVIDE COMFORT in Iraq, or even in Operation JUST CAUSE in Panama (which was not an example of OOTW): telephone interviews, Dr. Vernon Lowry, Chief of Analysis, Directorate of Evaluation and Standardization, U.S. Army School of Engineers, Ft. Leonard Wood; and Dr. Robert Wright, Historian, Joint Task Force South (and 18th Airborne Corps Historian in Panama at the time of JUST CAUSE).

militias.[107] In Operation PROVIDE COMFORT in Northern Iraq, U.S. forces had to contend with perhaps 3 to 5 million mines the Iraqis had sown in northern Kurdistan.[108] And U.S. forces now deployed in Bosnia regard local mine use as one of the main threats to U.S. forces in the region.[109] In such operations, landmine arms control (of any kind) would impose few meaningful limitations on U.S. forces, but might reduce the mine threat they would face. Even if hostile mine use were wholly unaffected by a treaty, the result would still be little worse than if there were no treaty at all.

For treaty and conflict types that would alter U.S. as well as hostile mine use, the effects of hostile noncompliance depend on the same (wide) range of variables described above, such as the balance of tactical offense and defense, mine types, terrain, and so on. The consequences of hostile violation would thus probably be greater for a ban on all mines than a ban on AP mines alone, for example, while the effects of AP violation would probably be greater for conflicts in rough terrain than for those fought in the desert. As for the offense-defense balance, the difference between violation and compliance would be greatest for mostly-offensive U.S. tactics (since this provides greater potential scope for hostile mine use); the more defensive the U.S. action, the smaller the role that hostile violation would play overall.

To provide an illustration of the possible magnitude of such effects, a third series of combat simulation analyses were conducted. These analyses focused on conditions likely to promote relatively heavy consequences for violation of an AP mine ban, and estimated the marginal effects of differing levels of violation for U.S. losses.

In particular, a series of scenarios were constructed around a dismounted assault by a U.S. mechanized battalion against an OPFOR motorized rifle company defending a roughly 2-kilometer frontage on rough, heavily wooded terrain in South Korea. An AP mine use ban was assumed to deny U.S. forces the use of scatterable AP mines in all cases. The scenarios differed in the number of AP mines available to support the OPFOR

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107 There were also substantial costs in time and effort spent in mine clearance: see, e.g., CAPT David A. Dawson, "Interview with LTC Holmquist, Commanding Officer, 1st Combat Engineer Battalion," Marine Corps Oral History Program, 30 January 1993, e.g. p. 8; idem., "Interview with CAPT Tim Myer, S3, 1st Combat Engineer Battalion," Marine Corps Oral History Program, 30 January 1993, e.g. p. 15. At one point, a French combat engineering platoon was tied down for a week clearing only 50 kilometers of heavily mined road: ibid. On U.S. mine casualties in Somalia, see Cahill, p. 3.

108 Human Rights Watch, *Deadly Legacy*, p. 188.

109 See, e.g., Christine Savem, "If U.S. Troops Get the Call in Bosnia, Mines Will Pose Serious Threat," *Defense Week*, 12 June 1995, pp. 1, 12; David Hackworth, "We're the Ones Who Die," *Newsweek*, 1995, pp. 32ff.

defender, ranging from about 900 (reflecting complete noncompliance) to zero (reflecting complete compliance).

The results are presented in Table IV-3 and illustrated in Figure IV-2. They suggest, unsurprisingly, that hostile noncompliance increases U.S. losses: when the OPFOR ignored the ban completely, mean U.S. infantry losses increased by about 30 percent (from 92.7 to 122.2); when OPFOR noncompliance provided only one-third as many mines, the increase in U.S. losses was about one-third the total (i.e., 10.6 of a maximum increase of 29.5).

Table IV-3. U.S. Infantry Losses as a Function of OPFOR Antipersonnel Mine Availability

OPFOR AP Mines Used	U.S. Infantry Losses *
0	92.7 [14.1]
300	103.3 [13.0]
600	124.0 [21.2]
900	122.2 [18.6]

* Entries provide mean U.S. infantry losses for 15 simulation repetitions; figures in brackets are associated standard errors. Note that, unlike the other simulation output described above, losses here are reported in infantry strength rather than in combat vehicles. In the U.S. defenses considered above, U.S. combat vehicle losses provide a meaningful common denominator for the performance of the defenses overall (U.S. AP mines that kill OPFOR infantry prevent that infantry from killing U.S. combatants of all types; hence, the effectiveness of the mines can be observed directly from either U.S. vehicle or infantry losses. Vehicle losses were selected because this provided a better representation of the effects of the OPFOR assault in the NTC scenarios, where the attacker rarely reached effective small arms range of U.S. infantry). Here, however, with U.S. dismounted infantry on the attack, OPFOR AP mines have only a very indirect effect on U.S. vehicle losses (i.e., by killing U.S. infantry which would otherwise kill OPFOR defenders that would otherwise kill U.S. vehicles), and no comparison is made with an all-mounted alternative case; hence, infantry casualties provide a more direct measure of the effect of the OPFOR's mines. Note also that, as Janus is a stochastic model, results vary from run to run: the reduction in mean infantry losses by 1.8 when OPFOR mine use increased from 600 to 900 is a result of such random variation and is not statistically significant.

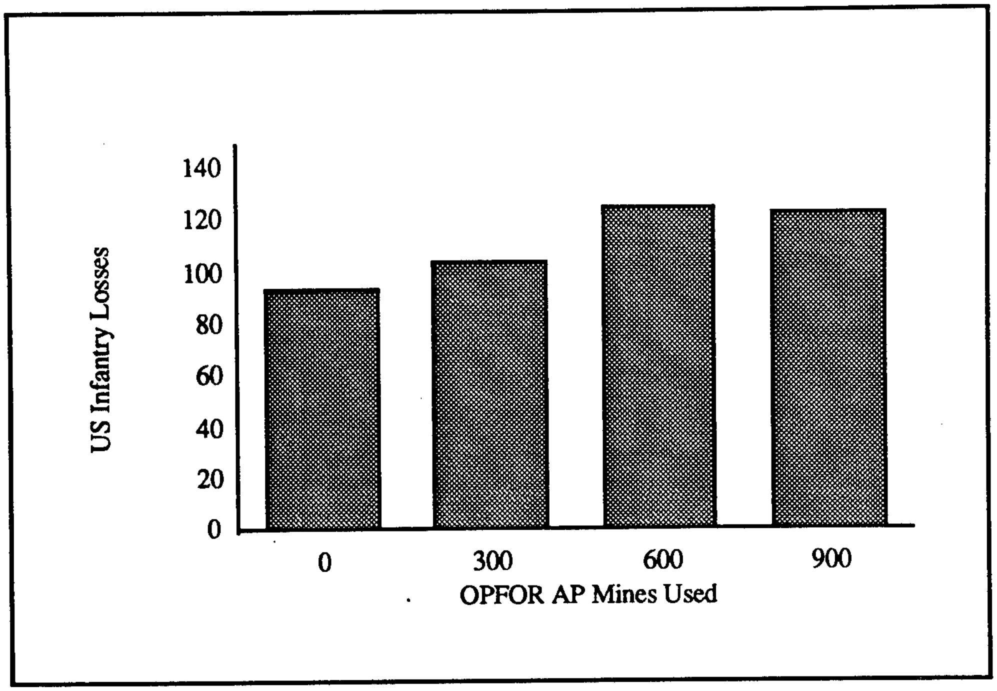

Figure IV-2. Effect of Hostile Noncompliance

In these runs, even substantial hostile noncompliance with an AP mine ban thus did not produce the factor-of-two increase in U.S. losses often cited in the debate, and the increase was roughly proportional to the scale of noncompliance. This is consistent with the mine-type analyses described above, and suggests that the effects of noncompliance are likely to mirror the effects of the mines in question. Where conditions tend to produce lower mine effectiveness, e.g., use of AP vice AT mine types, noncompliance will be less costly, and presumably vice versa.[110] Treaties limited to mine types with lesser relative effectiveness are thus likely to be less susceptible to the effects of any given level of noncompliance.

110 Note, however, that these runs were conducted under conditions likely to produce relatively heavy consequences for hostile violation of an AP mine ban (i.e., hostile forces in a pure tactical defense on rough terrain). While the focus on AP mines is likely to produce lower consequences for noncompliance than a focus on AT mines, the circumstances of these runs were conducive to high consequences for AP mine noncompliance per se.

V. CONCLUSIONS

As noted earlier, landmine arms control cannot be an open and shut case on analytic grounds. Any decision requires a value judgment to balance responsibility to third world civilians against responsibility to U.S. military personnel. Such a judgment is beyond our scope. We therefore will not provide a specific recommendation for U.S. government policy. Rather, our aim is to help inform the needed value judgment with a careful accounting of arms control's potential effects on the two groups.

Our findings suggest that the debate to date has often overestimated those effects.[111] First, arms control's ability to reduce civilian suffering in the third world has important limitations. It is difficult to raise the costs of mine use very much by arms control. A ban on mine production could be circumvented by shifting production to nonsignatory states, or concealing production at undeclared sites. Either would likely be highly effective and can be done at modest cost. A ban on mine exports could likewise be evaded by shifting production to states outside the treaty; alternatively, state-sponsored or private smuggling is likely to be effective and relatively inexpensive for small, easily concealed weapons like landmines. Bans on stockpiling and, especially, mine use are likely to be harder to evade successfully, though the attempt would impose little added cost on users. In these latter cases, sanctions would comprise the bulk of the costs imposed by arms control, but it is far from clear that the international community is prepared to impose heavy punitive sanctions on landmine users. And if it were, this would tend to discourage mine users from signing the treaty. It is possible that many of the world's heavier mine users would remain outside a treaty's reach in any event (either because mine-using states decline to sign any treaty, or because mine-using insurgent groups were beyond its reach), but the more effective the sanctions threat, the worse the problem becomes.

111 For documentation of claims made for and against landmine arms control in the public debate, see references in notes 22 and 81 above.

But unless mine use costs can be raised substantially, mine use incentives are unlikely to fall very far or very fast. Landmines are ideally suited to the needs of many third world militaries. Few real substitutes exist at anything like the cost. Even in the third world, AP landmine purchases consume only a small fraction of current military expenditures. Feasible cost increases could thus be absorbed with modest reallocations of effort, and states with few viable military alternatives are likelier to absorb a small cost increase than to forgo mine use.

Of course, none of this is to suggest that arms control would have *no* effect. A well-formulated treaty would surely increase the worldwide costs of landmine use to some degree, and any cost increase can be assumed to cause some reduction in use, saving at least some lives in the developing world. Moreover, some treaty types would likely be more effective than others: the greater difficulty of evading bans on mine use or stockpiling, for example, suggests that agreements including such limits may warrant particular attention by contrast with treaties restricted to export or manufacturing controls alone.[112]

It is also possible that a treaty might so stigmatize mine use as to cause potential users to forgo minelaying, even if it could not impose significant direct costs. Some states would comply with a treaty voluntarily in any event; others might succumb to political pressures and comply so as to avoid violating an international norm. No evidence has yet been advanced, however, to show that this would be a widespread result. The assumption by many landmine opponents that stigmatization will radically reduce minelaying is just that—an assumption. But neither can stigmatization be conclusively excluded as a possibility on the basis of what is currently known. What the present analysis *does* show is that *only* by assuming that stigmatization will work can one conclude that landmine arms control is likely to have a decisive effect on mine use. The monitoring and enforcement provisions of a treaty are unlikely in themselves to produce the effects often claimed for landmine controls in the public debate, and no analysis has yet been provided to show that confidence in stigmatization is warranted as more than an unproven assumption.[113]

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112 Although this trait would not in itself be sufficient to demonstrate the superiority of one treaty proposal over another; a wider range of issues (e.g., monitoring costs or negotiability—much less the military impact of the treaty) must be considered to sustain such a conclusion. The analysis above suggests only that treaties including use and/or stockpiling limits enjoy the advantage of more effective monitoring opportunities, and that this advantage may prove particularly important, but not that this property alone is necessarily decisive.

113 For documentation of claims for arms control's effectiveness, see references in note 22 above. On the evidentiary basis for stigmatization as a causal mechanism, see note 17 above.

But while arms control's effectiveness is often overestimated, it is also easy to overstate its risks. The military effects of landmines depend on the circumstances; hence, the increase in U.S. losses that might accompany a treaty will also vary. For some plausible circumstances, the consequences of a treaty would be as grave as often suggested; but for many others, the effects could be considerably less severe.

At a minimum, landmines' military effects will vary with changes in the balance of U.S. tactical offense and defense, the local terrain, the nature of the conflict, and the types of mines used, while the effects of a treaty would also be affected by our opponents' compliance rate. Some of these variables can be controlled: we choose what types of mines we will use, for example, and we can design a treaty to affect some types and not others. But many of these variables are either outside our control or impossible to predict with certainty. No one knows how much of the fighting in our next war will be tactically offensive for us, or what the terrain will be, or whether the next U.S. combat action will be OOTW, LIC, or an MRC. Given this, sensitivity analysis—or an assessment of how outcomes change as conditions change—is probably necessary to get a full picture of the effects of any given treaty.

While we have not attempted a complete or exhaustive sensitivity analysis for landmine effects in future conflict, the illustrative cases we have examined suggest the following: The worst increases in U.S. losses occur when total mine bans (i.e., elimination of all AT as well as AP mines) are applied in high intensity conflicts with purely defensive U.S. tactics and largely open terrain. Under such conditions, combat simulation results approached the oft-cited 100 percent increase; it is likely that modest changes in other variables (e.g., the local force ratio or hostile tactics) would cause the results to reach a factor-of-two effect.[114]

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[114] For arguments that a landmine ban would increase U.S. losses by 100 percent, see references in note 81 above. In addition, hostile noncompliance tends to worsen the military consequences of any treaty type regardless of U.S. tactics or other scenario conditions. As noted above, however, the magnitude of the effect varies with those conditions. And that magnitude is greatest under conditions where a treaty would hurt U.S. capability least. This is because nominal noncompliance makes little difference where the enemy wouldn't be using many mines anyway: e.g., when the enemy is attacking and the U.S. is on the tactical defense. Noncompliance makes the biggest difference where the enemy would choose to use mines in greatest quantity: e.g., when the enemy is defending and the U.S. is on the tactical offense. But since the U.S. tends to use fewer mines on the tactical offense, the difference between a treaty that bans U.S. mine use and no treaty is smaller here. Where a treaty affects U.S. mine use the most—tactical defense by the U.S.—our opponents use fewer mines anyway; hence, the impact of noncompliance on their part is smaller. As a result, although the consequences of hostile noncompliance are always bad for us, they tend to be worst where it matters least—and vice versa.

Under a variety of other conditions, however, the military effects of a treaty could be less damaging. A higher frequency of tactical offense by U.S. forces, for example, would imply less severe military consequences for a mine ban of any sort. The higher the frequency of peacekeeping, humanitarian relief, or other OOTW missions among future U.S. military actions, the lower the net negative consequences of a landmine treaty. Treaties limited to non-self-destructing or metal-free mines are likely to produce smaller increases in U.S. losses than would total bans, while treaties limited to AP mines are likely to produce smaller increases than bans that include AT types (and especially so for combat in mostly open terrain types where dismounted warfare is less frequent).[115]

While it is difficult to know just what the nature of future conflicts will be, or what terrain they will be fought on, or what the balance of tactical offense and defense by U.S. forces will be, it is at least plausible that OOTW may become increasingly frequent, or that future U.S. mechanized warfare may involve as much tactical offense as defense. Should this be the case, the effects of even a total mine ban would likely be smaller than often suggested. And other, less sweeping controls could be expected to have correspondingly smaller consequences.

Of course, this is not to argue that a mine ban would not cost U.S. lives in future conflicts. Under many if not all of these conditions, U.S. losses would still increase as a result of a treaty. The *magnitude* of the increase matters, however, for judging any given arms control proposal. And for a variety of plausible assumptions, the magnitude of the increase could be considerably smaller than often suggested in the public debate.

The value judgment needed to reach a decision is thus likely to be a closer call than the debate to date often implies. This suggests that, whatever the ultimate decision on arms control, other approaches to the landmine problem at least merit continued attention.

Demining improvements, for example, may provide a promising avenue—whether alone or in conjunction with some form of arms control or changes in the law of war. Even if a mine use ban halted all further minelaying tomorrow, it would still leave behind the 80 to 110 million AP mines that have already been sown. At the current rate of demining, it will take decades to remove these mines. In the meantime, third world civilians will suffer tens to hundreds of thousands of additional injuries even if no additional mines are planted.

115 In fact, under some conditions such bans might reduce—rather than increase—U.S. casualties: see discussion above.

And with current demining methods, the injury toll will eventually include perhaps an additional 30,000 deminers killed or maimed in the clearance effort—or roughly half the number of Americans killed in the Vietnam War.[116]

For now, however, demining methods are extremely primitive.[117] While mine-sniffing dogs, metal detectors, flails, or rollers can sometimes help, most mines must eventually be removed by human beings on hands and knees, probing the ground with sticks, fiberglass rods, or bayonets. Not only are such methods risky, they are also expensive and slow. It has been estimated that an effective demining program would require at least a 50-fold increase in the cost-effectiveness of current techniques; without concerted effort such an improvement will be extremely difficult to obtain.[118]

Fortunately, technological opportunities do exist for a more effective capability. These include vehicle-mounted infrared, ultraviolet, ground penetrating radar, or neutron backscatter detection devices; automated mechanical or explosive clearance systems; and improved navigational equipment for faster, more accurate surveying.[119] While their effectiveness and cost remain to be established, and while an assessment of such technologies would be beyond the scope of this paper, it is at least clear that a variety of possible approaches exist for reducing the human costs of mine use. Given the inherent limitations of arms control or any other individual approach taken alone, any effective strategy must include at least a careful exploration of all such possibilities.[120]

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116 This estimate reflects current demining accident rates of one per 1,000 to 2,000 mines cleared, and assumes that only half the world's currently sown mines are ever removed. On accident rates, see Blagden, p. 115.

117 On current demining methods, see Blagden, pp. 112–23; Human Rights Watch, *Deadly Legacy*, pp. 234–60. Note that humanitarian demining—an area clearance operation with very high percentage clearance requirements—is a very different undertaking from military breaching, which is typically performed in narrow breaching lanes for relatively short distances with much less demanding percentage clearance requirements. As such, the procedures and equipment for the two jobs are very different, and those for the former are typically much less technologically mature than for the latter.

118 Blagden, p. 114.

119 For surveys of possible approaches, see, e.g., Evans, pp. 124–137; Robert Zirkle, et al., *Improved Peace Enforcement Capabilities*, briefing slides, Institute for Defense Analyses, 22 September 1995, pp. 4–12.

120 For other calls for multiprong approaches, see, e.g., Cahill, p. 5.

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13. ABSTRACT *(Maximum 200 words)*

Perhaps 80 to 110 million unexploded mines are now scattered over 64 countries worldwide. These mines kill or maim as many as 2,000 people a month—most of them civilians, many of them children. The purpose of the paper is to evaluate the pros and cons of addressing this problem via negotiated arms control agreements to ban the production, stockpiling, export and/or use of mines.

Our principal findings are that neither the costs nor the benefits are likely to be as great as many have argued. Because costs and benefits are incommensurate, landmine arms control could not be an open and shut case—either for or against—on its analytical merits, but the value judgment required to reach a conclusion is likely to be a closer call than many in the current debate would suggest.

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